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A Study of Residual Activity in Temporalis Muscle

Naishadh Parikh

Loyola University Chicago

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**A STUDY OF RESIDUAL ACTIVITY IN
TEMPORALIS MUSCLE**

by

NAISHADH PARIKH

**A Thesis Submitted to the Faculty of the Graduate School
of Loyola University in Partial Fulfillment of
the Requirements for the Degree of
Master of Science**

JUNE

1960

LIFE

Naishadh Parikh was born in Bombay, India, on April 24, 1935. He graduated from the Fellowship High School, Bombay, India, and passed the Secondary School Certificate Examination held by the board of education, Government of Bombay, India, in May 1949. From June 1949 to May 1951 he attended St. Xavier's College of Bombay University, Bombay. He enrolled at the Nair Hospital Dental College in June 1951 and completed his studies receiving the diploma of Licenciante in Dental Science (L.D.Sc.) in May 1955. From June 1955 to May 1956 he did post-graduate studies in Orthodontics and half-time internship in Prosthetic Dentistry at the Nair Hospital Dental College. In September 1956 he came to United States of America and served as an intern till June 1957 at Forsyth Dental Infirmary for Children, Boston, Massachusetts. He began his graduate studies at Loyola University in June 1957.

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TABLE OF CONTENTS

Chapter	Page
I. INTRODUCTION:	
A. Introductory Remarks and Statement of the Problem. . .	1
B. Review of the Literature	2
II. MATERIALS AND METHODS:	
A. Selection of the Subjects.	15
B. Electrodes	15
C. Technic for Electrode Placement.	16
D. Position of the Patient.	17
E. Electronic Equipment	18
F. Methods.	18
G. Stastistical Discipline.	20
III. EXPERIMENTAL RESULTS:	
A. General Findings	33
B. Residual Activity after the Exercise of Saying "Mississippi".	35
C. Residual Activity after the Exercise of Swallowing . .	37
D. Residual Activity after the Exercise of Maximal Opening.	39
IV. DISCUSSION	55
V. CONCLUSION AND SUMMARY	68
VI. BIBLIOGRAPHY	70

LIST OF FIGURES

Figure	Page
1. DUAL ELECTRODES ON THE ANTERIOR, MIDDLE, AND POSTERIOR FIBERS OF LEFT TEMPORAL MUSCLE.	21
2. INJECTING ELECTRODE JELLY UNDER THE ATTACHED ELECTRODE WITH A SYRINGE	22
3. OHMMETER USED FOR TESTING SKIN RESISTANCE	23
4. SUBJECT SEATED IN THE FARADAY CAGE, SHOWING ELECTRODE TERMINAL BOX, MIRROR ON THE STAND, AND THE POSITION OF THE SUBJECT	24
5. A MIRROR WITH THE HORIZONTAL LINE FOR HEAD ORIENTATION. . . .	25
6. THE ELECTROMYOGRAPH EQUIPMENT, SHOWING THE POWER SUPPLY UNIT, AMPLIFIER UNIT, CRYSTOGRAPH, AND TIME BASE MARKER	26
7. CRYSTOGRAPH WITH A PEN FOR TIME BASE MARKER	27
8. THE CESSATION OF THE ACTIVITY AND THE ONSET OF THE REST PERIOD.	28
9. SKETCH SHOWING RECORDED ONE MINUTE REST PERIOD DIVIDED INTO FOUR EQUAL PARTS, FIFTEEN SECONDS EACH, AND THE RANDOM SELECTION OF ONE SECOND PERIOD FROM EACH PART	29
10. RANDOMLY SELECTED ONE SECOND PERIOD SHOWING AMPLITUDE AND FREQUENCY OF WAVES MEASURED FOR THE STATISTICAL ANALYSIS. . .	30
11. VERNIER CALLIPERS, EYE-PIECE WITH THIRTY-THREE TIMES POWER OF MAGNIFICATION, AND A SCALE.	31
12. CALIBRATION AT TEN MICROVOLTS INPUT.	32
13. GRAPH SHOWING AVERAGE MICROVOLT-SECONDS AT REST AFTER THE DIFFERENT EXERCISES	41
14. GRAPH SHOWING AVERAGE MICROVOLT-SECONDS FROM THE TEMPORAL MUSCLES DURING ONE MINUTE PERIOD.	42

15. GRAPH SHOWING THE VARIATION BETWEEN THE AVERAGE MICROVOLT-SECONDS RECORDED FROM EACH SUBJECT AND THEIR AGE. NOTE THE VARIATION BETWEEN THE SUBJECTS. 43
16. ELECTROMYOGRAPH RECORD OF SUBJECT NUMBER EIGHT SHOWING THE RESIDUAL ACTIVITY FROM THE ANTERIOR, MIDDLE, AND POSTERIOR FIBERS OF THE RIGHT AND LEFT TEMPORAL MUSCLES AT MANDIBULAR REST AFTER THE EXERCISE OF SAYING "MISSISSIPPI" 44
17. ELECTROMYOGRAPH RECORD OF SUBJECT NUMBER EIGHT SHOWING THE RESIDUAL ACTIVITY FROM THE ANTERIOR, MIDDLE, AND POSTERIOR FIBERS OF THE RIGHT AND LEFT TEMPORAL MUSCLES AT MANDIBULAR REST AFTER THE EXERCISE OF SWALLOWING 45
18. ELECTROMYOGRAPH RECORD OF SUBJECT NUMBER EIGHT SHOWING THE RESIDUAL ACTIVITY FROM THE ANTERIOR, MIDDLE, AND POSTERIOR FIBERS OF THE RIGHT AND LEFT TEMPORAL MUSCLES AT MANDIBULAR REST AFTER THE EXERCISE OF MAXIMAL OPENING. 46
19. ELECTROMYOGRAPH RECORD OF SUBJECT NUMBER NINE SHOWING THE RESIDUAL ACTIVITY FROM THE ANTERIOR, MIDDLE, AND POSTERIOR FIBERS OF THE RIGHT AND LEFT TEMPORAL MUSCLES AT MANDIBULAR REST AFTER THE EXERCISE OF SAYING "MISSISSIPPI" 47
20. ELECTROMYOGRAPH RECORD OF SUBJECT NUMBER NINE SHOWING THE RESIDUAL ACTIVITY FROM THE ANTERIOR, MIDDLE, AND POSTERIOR FIBERS OF THE RIGHT AND LEFT TEMPORAL MUSCLES AT MANDIBULAR REST AFTER THE EXERCISE OF SWALLOWING 48
21. ELECTROMYOGRAPH RECORD OF SUBJECT NUMBER NINE SHOWING THE RESIDUAL ACTIVITY FROM THE ANTERIOR, MIDDLE, AND POSTERIOR FIBERS OF THE RIGHT AND LEFT TEMPORAL MUSCLES AT MANDIBULAR REST AFTER THE EXERCISE OF MAXIMAL OPENING. 49
22. ELECTROMYOGRAPH RECORD OF SUBJECT NUMBER THREE SHOWING THE RESIDUAL ACTIVITY FROM THE ANTERIOR, MIDDLE, AND POSTERIOR FIBERS OF THE RIGHT AND LEFT TEMPORAL MUSCLES AT MANDIBULAR REST AFTER THE EXERCISE OF SAYING "MISSISSIPPI" 50

Figure

Page

23. ELECTROMYOGRAPH RECORD OF SUBJECT NUMBER THREE SHOWING THE RESIDUAL ACTIVITY FROM THE ANTERIOR, MIDDLE, AND POSTERIOR FIBERS OF THE RIGHT AND LEFT TEMPORAL MUSCLES AT MANDIBULAR REST AFTER THE EXERCISE OF SWALLOWING 51
24. ELECTROMYOGRAPH RECORD OF SUBJECT NUMBER THREE SHOWING THE RESIDUAL ACTIVITY FROM THE ANTERIOR, MIDDLE, AND POSTERIOR FIBERS OF THE RIGHT AND LEFT TEMPORAL MUSCLES AT MANDIBULAR REST AFTER THE EXERCISE OF MAXIMAL OPENING. 52
25. ALTERNATE HIGH AND LOW VOLTAGE ACTIVITY IN THE MIDDLE AND POSTERIOR FIBERS OF THE RIGHT TEMPORAL MUSCLE FROM THE . SUBJECT NUMBER ONE. 53
26. ILLUSTRATION OF THE SENSITIVITY OF THE ELECTROMYOGRAPH EQUIPMENT. NOTE: A STRAIGHT LINE RECORDED BY THE CRYSTOGRAPH PEN UP TO THE GAIN EIGHT AND PEN DEFLECTION DUE TO HIGH CYCLE AMPLIFIER NOISE AT GAIN TEN 54

LIST OF TABLES

Table	Page
I. NAME OF SUBJECTS, THEIR AGE, APPROXIMATE LENGTH OF TIME THEY WERE EDENTULOUS, AND AVERAGE ENERGY OUTPUT PER SECOND BY THE TEMPORAL MUSCLES	74
II. ANALYSIS OF VARIANCE TABLE	75

CHAPTER I

INTRODUCTION

A. Introductory Remarks and Statement of the Problem

Mandibular musculature of patients with full complements of teeth usually shows no electrical activity during rest. Jarabak has shown that this does not necessarily hold for edentulous subjects. He observed low amplitude residual activity resembling fasciculation while the mandible was at rest in some of his subjects. This lack of complete cessation of electrical activity led him to conclude that the mandibular musculature at rest is rarely devoid of all motor activity. It further led him to believe that an edentulous patient, having lost proprioception from the periodontium, is deprived of a mechanism needed to govern the mandibular posture, and is therefore constantly seeking a point of reference.

This study was undertaken to establish the prevalence of residual motor activity in the temporal muscles of edentulous subjects. It was further planned to attempt to determine how much of this activity was fasciculation and how much of it is idiopathic.

Here are some of the questions we will be attempting to gain information on: Is this behavior due to anomalies in proprioception? Is it due to altered tonicity? Is it due to stimuli originating in the central or periph-

eral nervous system? Or, is it due to degenerative changes in the central nervous system?

B. Review of the Literature

Luigi Galvani in 1791 was the first to demonstrate that muscle had two fundamental electrical properties: (1) that muscles contract when electrically stimulated, and (2) that an electrical current is produced by the muscle during its contraction.

The earliest observations of electrical response from muscles were made with a static needle galvanometer. Later the capillary electrometer and string galvanometer were used. The currents produced by muscle activity are oscillatory in nature, and these instruments possessed too much inertia to follow these oscillations accurately. The cathode ray oscilloscope, which is an inertialess system, was later adapted to these studies by Erlanger and Gasser in 1921.

Later in 1929, permanent written records of the electrical activity of muscles were obtained by means of an instrument called the electromyograph. The electromyograph is at present the instrument of choice for muscle studies. The electrical activity from the muscle is received by electrodes attached to the skin over the muscle or by needles inserted into the muscle itself. The currents are then relayed to the amplifier which amplifies them several thousand times. The amplified signals are finally conveyed to a transducer

from which a written record is obtained.

Physiologically a muscle consists of bundles of muscle fibers called motor units innervated by a single motor neuron. The electrical activity arising from a motor unit is called an action potential. These units of electrical activity, action potentials, are the things recorded by the electromyograph.

Adrian and Brenk (1929), Smith (1934), Lindsay (1935), Hoefer and Putnam (1939), Weddell, Feinstein and Pattle (1944), and others, using this instrument found that relaxed muscles showed no detectable electrical activity.

It is, nevertheless, a basic physiologic assumption arising from the classical work of Sherrington in 1915, that live muscles, even though at rest, are under constant activity called "tonus". The electromyograph can not detect this activity.

Hoefer, in his later publication (1941), states that the striated muscle is normally under a constant tension even at rest, and removed from the influence of gravity. An increase in tension beyond what is seen is noticeable in muscles or muscle groups serving to maintain posture as in standing, without obvious movements.

Gilson and Mills (1941) studied the electrical responses of the flexor digitorum sublimis muscle. They found that no activity was obtained with muscle either relaxed or under a tension of twenty grams when the arm was well supported. If the arm was not properly supported then spontaneous activity was obtained.

Besma and Gellhorn (1946) reported that the potentials can be recorded from the resting muscles. These potentials were not considered true action potentials, but probably the result of the nerve impulses which maintain muscle tone.

Ralston (1953), while discussing the question of tonus in the skeletal muscle, states:

"It has been uniformly observed that in the relaxed human subjects, sitting or lying down, there is no detectable persistent background of electrical activity in many muscles that have been examined in the trunk, limbs and jaws. These muscles are electrically silent unless the individual tenses them. During easy standing there is no activity in these muscles, even in such postural muscles as the erector spinae, except as follows: if he sways sufficiently, there may be short bursts in the appropriate muscles restoring position."

In answering the question "what does maintain a sitting or standing posture if not relatively continuous active muscle contractions serving to lock the joint in position," he states: "In addition to a variable amount of balancing of body parts on the bony skeleton, tissue elasticity (i.e., passive stretch tension of the fascial sheets, ligaments and muscles) is usually made use of to a significant degree before motor unit activity is called into play."

Joseph, Nightingale and Williams (1955), during their observations over postural muscles while relaxed and standing, found that potentials of up to 7 uv. occurring about 40-50/sec. are recorded in addition to the potentials due to noise level of the apparatus, in the relaxed muscles in the lower limb as well as over the bony surface of the tibia and over the patella.

They further state:

"These electrical fluctuations may be due to the 'miniature-end-plate potentials' described by Fatt and Katz (1952). Other

possible sources are the irregular flow of ions through the vessels and the thermal agitation of electrons and ions giving rise to phenomena similar to 'thermal noise' in resistors and the 'flickers' effects in valves. No conclusion to prove these have been found."

"If no evidence of motor activity in relaxed muscles can be found even with a very high degree of amplification, it suggests that 'tone', which is said to be present in relaxed muscles, is not due to small number of motor units 'firing off' in a rotatory manner."

Spontaneous activity is seen in resting muscle in certain neurogenic diseases. These involuntary contractions are either fasciculations or fibrillations. In 1938, Denny-Brown and Pennybecker wrote a paper differentiating these two terms.

Hyperactivity of motoneurons in diseases such as progressive muscular atrophy or amyotrophic lateral sclerosis results in regularly periodic discharges of single impulses by the motor neuron. These involuntary sustained contractions at rest are muscle fasciculations. Its duration, recorded electromyographically, is about eight to twelve milliseconds and it therefore can be recorded with ink-writing oscillographs of the electroencephalograph machine. Its amplitude may be .561 millivolts.

Twitches are lowest discharge rate of spontaneous contractions observed in clinical neurology. The latter may be coarse and clearly visible or so minute as to be revealed only by the amplified and recorded electrical component of the twitch. Denervated muscle fibers contract periodically and the confused medley of small twitches constitute true fibrillation.

In presence of fatigue or excessive loss of sodium chloride, involuntary

muscular contractions appear. Those due to fatigue are small bursts of contractions in a fasciculus, and are of a type such as would be caused by irregular discharge spreading to and through all the nerve bundles in the fasciculus. Those of myokemia, associated with the hyperidrosis, are of similar nature, but of more widespread distribution and more extensive discharge. Both are clearly related to muscular cramp. The prolonged discharge compared with the single twitch of fibrillation and fasciculation of neuron discharge gives the resulting fascicular movement a slower undulating appearance.

Hoefer and Putnam (1940) observed no 'spastic' innervation of a resting muscle and concluded that spastic 'tonus' does not exist except as a reflex innervation facilitated by the general irritability. Spastic resistance is therefore probably to be considered a reflex phenomenon produced by stretching of a muscle either by the examiner or by the patient himself.

Later that year, they studied rigidity, tremor and reflexes under various conditions by electromyography. Here they observed Parkinsonian tremor characterized by a continuous slight innervation of the rigid muscles even when the limb was placed in its most relaxed position. No such constant innervation has been observed in cases of spasticity.

They also observed that the stretching of a rigid muscle by means of active or passive movement produces a marked increase in this innervation. In this respect rigidity resembles spasticity.

Now let us review the literature pertaining to the physiology of the masticatory musculature, mainly temporal muscles, and the physiologic rest position of the mandible. Speaking of the rest position of the mandible, Sicher states:

"The rest position is constant in each individual due to individually fixed and only slightly variable tonus of the masticatory muscles, which in their 'relaxation' allow the mandible to drop slightly. The rest position is therefore not dependent on the teeth or on their shape or position but on the musculature and muscular balance only."

"It is tonus of the masticatory muscles which does not allow the mandible to drop farther and fixes individually the rest position. If the muscles rest, they do not relax entirely. Instead, a certain percentage of fibers of an individual muscle remain in the state of contraction. In spite of the incapability of the striated muscle fibers to keep contracted to any length of time, the muscle as a whole maintains slight contraction or tension, which is termed tonus, by groups of fibers relieving each other in short intervals. For each muscle and each individual, the tonus is fairly constant."

The introduction of electromyography in dental science for studying the behavior of the oral and facial musculature is very recent. Moyers (1949) first studied the behavior of the masticatory muscles during temporomandibular movements and introduced electromyography in dentistry. Since then many other scientific investigators have studied in this field of dentistry.

Perry (1954) suggested the use of electromyography and surface electrodes to prosthodontists and orthodontists to determine the physiologic rest position. He found that there is a minimal amount of electric discharge from a muscle at its resting length which is associated with tonus. Slight man-

dibular movements, imperceptible to the observer, are recorded from the temporal and masseter muscles with the electromyograph.

Discussing the interpretation of the electromyograph records in dental science, Sicher (1954) states:

"The electromyograph registers the action potential of a muscle, that is it shows when and how strongly a muscle acts, but it does not and can not show in which capacity the muscle activity occurs. Muscle can contract isotonicallly or isometrically. If they contract isotonicallly, they shorten and retain tension; if they contract isometrically, they tense but do not shorten and thus retain their length."

Moyers (1949, 1950) studied the electrical activity of the temporal muscle from three different parts, the anterior, middle and posterior fibers. He observed that the tonus of the muscle displayed, while maintaining the mandible at physiologic rest position, was equal in all parts of the temporal muscle in normal individuals. In some cases of mandibular retrogression, the spike potentials recorded from the posterior fibers of temporal muscle were greater than those recorded from the middle and anterior fibers of the same muscle while mandibular posture is being maintained.

MacDougall and Andrew (1953) studied the behavior of the masseter and temporal muscles during normal movements of the lower jaw by electromyography. They recorded slight activity at rest, but it was considered to be due to the tone of the muscle. Thus considering this as the base line, no electrical activity was recorded when the jaws were at rest. He also observed that during the movement of closing the jaw against the gravity alone, a slight

activity was recorded as against closing the jaw with a small object between the teeth.

Ballard (1955) has discussed the physiologic background of the mandibular posture and movement. He found electromyographically that there is a minimum of electrical activity in the muscles which maintain the mandibular posture when the individual is sitting upright, has the natural position of the head, and is looking straight forward. He believes that the posture is not maintained as the result of the reciprocal activity of groups of muscles at physiological resting tonus. If the individual is inverted, the mandible maintains the postural relationship to the maxilla, but quite obviously the pattern of muscle activity had to be changed. He believes that the postural position is the property of the central nervous system. In the majority of the individuals, the postural position of the mandible is maintained even during sleep. Thus he prefers the term 'endogenous postural position' to 'physiological postural position'.

He further states that the pattern of activity during endogenous postural position may not be produced if the individual's head is clamped in a cephalostat or if he is told of what the observer wants. Only by careful clinical observation can the true postural position be found in each individual and when found it can then be reproduced for the purpose of recording, radiographically or by other means.

While discussing the physiology of centric and other jaw relations,

Moyers (1956) states:

"Any patient presenting for complete denture prosthesis has suffered from a poor occlusal history, or he would not be needing prosthetic service. A high percentage of such patients must have practiced various eccentric patterns for years prior to the loss of all their teeth. While the teeth are in the mouth, the periodontal membranes serve as an important source of afferent signals for muscle regulation. Once the teeth and the enclosing periodontal membranes are lost, the position of the mandible is determined almost solely by the proprioceptors within the muscles and the capsular joint."

Jarabak (1957) observed the muscular behavior in the mandibular movements from rest position in edentulous subjects, most of whom had worn dentures for some time that functioned through an excessive interocclusal distance. As a control group, he used subjects with good occlusion and whose interocclusal distance ranged from two to four millimeters. From the records of the subjects with normal occlusion, while studying rest activity, after the letter "M" had been repeatedly spoken, it was gathered that there was complete electrical silence in temporal, masseter and digastric muscles. While studying the physiologic rest of the same muscles in edentulous subjects, it was found that spontaneous hyperactivity would invariably appear in temporal and digastric muscles at rest, if subjects had worn dentures which functioned through an excessive interocclusal distance. Although this hyperactivity continued even after the removal of the denture, it would be inhibited only after dentures with correct interocclusal space was placed. Here also, these muscles took some time to adapt themselves before the hyperactivity ceased, Jarabak

also observed that this hyperactivity was maximum while the mandible was at rest. It either diminished or disappeared with the slow voluntary movements of the mandible in either vertical or horizontal direction. From this it is obvious that these tremors were present because the muscles did not function within the perimeter of its normal physiologic muscle length, but that the tension recorded in the muscle and tendon proprioceptors are altered due to the incorrect interocclusal distance.

Latif (1957) did an electromyographic study of the temporal muscle on twenty-five children aged ten to fourteen years, with normal dento-facial structures. He observed that the temporal muscle maintained the mandibular posture in the physiologic resting position, the posterior fibers taking more active part than the anterior fibers. He confirmed the findings of MacDougall and Andrew.

Javois (1956) did the combined study of electromyograph and cephalometric roentgenograph of the rest position of the mandible and the interocclusal clearance. Here, first the rest position was established by the electromyograph and then the cephalometric roentgenograph records were obtained. The pen deflection for each subject and each muscle was adjusted so that the minimal activity from the muscle was easily defined. However, in no case was the deflection adjusted to a degree where no activity could be discerned. If the activity dropped to a level at which the pen recorded a straight line, the equalizer was adjusted to obtain some deflection. Once established, the

pen deflection remained constant while the two cephalometric radiograph records were obtained. In the conclusion he stated that a low level activity may be recorded electromyographically from muscles which are presumably maintaining posture.

Mullen (1956) recorded two identical electromyograms of minimum muscular activity associated with postural position from masseter, anterior fibers of temporal and suprahyoid muscles. He found electrical activity coincident with the postural position of the mandible. He states that the electromyogram must have high sensitivity to record minimum muscular activity. He states the possibility of higher centers affecting the postural position. All muscles of the group maintaining the posture work synchronously.

Lemie, Peery and Crumm (1958) also did the electromyographic observation on complete denture patients. They recorded minimal muscular activity from the temporal muscle without the dentures in place. The minimum muscular activity was obtained with the placement of the "muscular denture". A great deal of muscular activity was discharged from the temporal muscles when the second open denture (with ten millimeters vertical displacement) was inserted. He feels that this may be probably a stretch-reflex type firing of the nervous units initiated by the increased vertical dimensions. It is conceivable that the afferent signals of this stretch reflex firing could arise from the temporomandibular joint or oral mucosa as well as the muscles themselves. Possibly all three contributed to some degree.

Speaking of the proprioceptive nerve endings they said that in normal individuals these are found not only within and about the temporomandibular joint and the surrounding musculature, but a third group of proprioceptive fibers are found in the periodontal membranes of all teeth which direct the action of the temporomandibular joint.

Jense (1959) studied the face height electromyographically in complete artificial denture subjects. He used crystograph and electronic integrator to record the rest potentials from the anteromedial fibers of the temporal and masseter muscles. He observed the rest potentials before the insertion of complete artificial dentures, after wearing the dentures approximately one week, and after wearing them for two to four months with dentures out of the mouth and in place. Cephalometric radiographs were also taken at the same time to compare the rest vertical dimensions. There was no significant difference found, in his study, between the rest vertical dimensions of the face during different recordings, indicating that the rest vertical dimension of the face is quite stable. All these records were obtained with the head and mandible in their natural position as well as when clamped in cephalostat. He concluded that there was no significant difference between these two recordings. He also compared the rest vertical dimension of the face, with the complete dentures out of the mouth after wearing them for two to four months, with the occlusal vertical dimension recorded at the same time with dentures in place. The potentials recorded showed sufficient difference in

their magnitude which was smaller during rest than in occlusion. During this study he also noted that more than half of his subjects had complete dentures with a greater than average interocclusal clearance.

Garnick (1959) studied the rest position of the mandible both clinically and electromyographically in twenty subjects. Electromyographically he observed the behavior of the temporal, masseter and anterior digastric muscles. Establishing the rest position clinically, he recorded small amplitude potentials which he described as tonus activity. Establishing the rest position electromyographically, he found a wide "resting range" in these muscles. He defined rest position electromyographically as the point or area where the muscular potential was least. In the majority of the cases in his study the temporal muscles were at rest from maximal opening to light contact of the teeth. This range for the anterior fibers of the temporal muscle was 17.9 mm. and for the posterior fibers of the same muscle was 17.2 mm. It was suggested that the changes in the activity of the temporal muscles decreased or increased the resting range and indirectly the free way space. He also observed that the clinically and electromyographically determined rest position did not coincide in most cases. In thirteen out of twenty subjects the clinical rest position was not even located in the range of minimal muscular activity.

CHAPTER II

MATERIALS AND METHODS

A. Selection of Subjects

The edentulous subjects ranging in ages from forty to seventy years were used in this study. The subjects were selected at random from the patients of the Prosthetic Department of the Loyola University School of Dentistry. Only those patients were selected who had all their teeth extracted two months to one year prior to the testing, because this experiment is designed to study the residual activity of the temporalis muscle during physiologic rest of the mandible in the edentulous patients before placement of the prosthetic appliance.

B. Electrodes

The literature covers various types of electrodes used in electromyography. In this experiment surface silver disc electrodes 8 mm. in diameter were used (Fig. 1). Absence of underlying superficial or adjacent muscle tissues makes the use of this type of electrode more practical for the temporal muscle than needle electrode. These electrodes were attached over each temporal muscle, one in the area of anterior, another on the middle and the third on the posterior fibers (Fig. 1). Thus, each of the three parts of the temporal muscle had an electrode placed over it. The fibers of this

muscle are as follows: the anterior fibers are directed vertically downwards, the middle fibers obliquely, and the posterior fibers horizontally. These three areas of the muscle were studied during the mandibular movements. For the topography of the electrode placement, the patient was asked to close maximally, the temporal muscle was then palpated with fingers. This muscle "fans" from the posterior surface of the eye posteriorly to the anterior surface of the ear and slightly above it. The anterior and posterior borders were selected for the placement of the electrodes on the anterior and posterior fibers respectively while the principal belly of the muscle was selected to represent the middle fibers.

C. Technic for Electrode Placement

The skin in the selected area was washed with soap and water, and then acetone. Then it was rubbed with electrode jelly to reduce the skin resistance. Washing the area with soap and water removes the skin oils which make the skin resistance too high for accurate recordings. Frequently, the area was shaved, if it was found necessary to expose the skin (Fig. 1). Each electrode was secured to the skin with collodion (Fig. 1). After the collodion dried, electrode jelly was injected under the electrode, through a small hole in the center of it, with a blunt hypodermic needle attached to a syringe (Fig. 2). Readings were taken with an ohmmeter to determine that a skin resistance of 5,000 ohms or less was obtained (Fig. 3). A second electrode

was attached on three given muscle groups about 1 cm. apart from the first one (Fig. 1). Dual electrodes were placed on the muscle instead of using a single electrode with the ear lobe for the reference electrode. This was done to reduce the distance between the two electrodes to a minimum, so that maximum activity could be picked up from the area with the minimum of interference from the other fibers. Six pairs of electrodes were used, three pairs on each temporal muscle. The ground electrode was attached to the left arm (Fig. 1).

D. Position of the Patient

The patient was seated in a Faraday cage (Fig. 4). Both, patient and the cage, were connected to the ground to eliminate extraneous noises which might mask action potentials from the muscles. To orient the head on the Frankfort horizontal plane, a mirror was placed at the eye level on a stand facing the subject. A horizontal line in the middle of the mirror coincided with an imaginary line drawn through the center of the pupils (Fig. 5). The patient was advised to keep the head in the same position during the record tracing procedure. Previous research has shown no electrical activity in the temporal muscle at rest when the head was oriented on the Frankfort horizontal plane.

E. Electronic Equipment

The electrode wires from each area were led into the terminal box situated inside of the Faraday cage (Fig. 4). From this box, the impulses were fed into the amplifier system of an Offner Encephalograph, Type A, which was adjusted to record high frequencies. The electromyograph consists of a power supply and six amplifier units which record simultaneously (Fig. 6). The output signals from these amplifiers pass to the six-pen crystographic ink writer (Fig. 7). The instrument was calibrated for equal pen deflection at ten microvolt peak input. A paper speed of 2.5 cm. per second was used for all the readings in this experiment. The instrument was calibrated prior to each run and after each run. A time base marker was connected to a separate pen affixed to the crystograph. It was adjusted to make a deflection every tenth of a second.

F. Methods

In order to establish the correct rest position of the mandible, each subject was asked to perform three different exercises. The exercises are as follows:

1. To open and close slowly, then rest for one minute.
2. To say the word "Mississippi", then rest for one minute.
3. To swallow, then rest for one minute.

These exercises were selected because they are used to establish the

physiologic rest position of the mandible clinically. Each exercise was performed ten times, after which the subject was asked to rest for one minute. Complete randomization was employed to determine the sequence of the exercises. Electrical activity was recorded from the temporal muscles during these exercises and the ensuing rest periods (Fig. 8). It was easily possible to distinguish between the regular activity from the muscles and the irregular disturbances in the base line caused by the noises within the amplifier circuits. Four or five recordings were obtained for each exercise.

It was necessary to reduce the data to numerical form so that they can be subjected to appropriate analysis of variance. The activity during physiologic rest of the mandible from three parts of the temporal muscle was recorded for one minute. This one minute period was divided into four equal parts, i.e., each part consists of fifteen seconds. One-second period was selected at random from each of these four parts. Thus four one-second periods were selected at random from a one-minute recording (Fig. 9).

Each wave from this one-second period (Fig. 10) was measured in centimeters with a Vernier caliper (Fig. 11). These were added to get the total centimeters of wavers per second. This sum was divided by the number of wavers measured to get the average centimeters per wave. Using calibration at ten micro-volt peak input, this average centimeters per wave is changed into micro-voltage (Fig. 12). Multiplying this average micro-voltage by the number of measured waves would give the microvolt-seconds, a unit used for

the statistical analysis.

G. Statistical Discipline

In order to establish the validity of the experiment for statistical analysis, a complete randomization was employed to determine the sequence of the exercises. The subjects were selected at random within the categories described. The one-second sample of tracings were selected at random within the quarter of a minute following the cessation of the exercise. Duplicate readings were obtained from among four or five trials.

The experiment was designed to reveal the differences caused by variations from one subject to another. It was also designed to reveal the differences in the energy output of right and left temporal muscles and of the divisions of these temporal muscles. It would also disclose the differences between the "resting" activities within these muscles following the three different exercises. It was intended to show whether there was any change in the activity of these muscles during one minute period following the three exercises. It would also reveal whatever interactions among these main effects that might be significant. It was necessary to transform the microvolt-second figures by means of the square root transformation so that the familiar analysis of variance scheme could be employed in a valid manner. The results of this analysis appear in Table II.

Figure 1

Dual electrodes on the anterior, middle, and posterior fibers of the left temporal muscle.

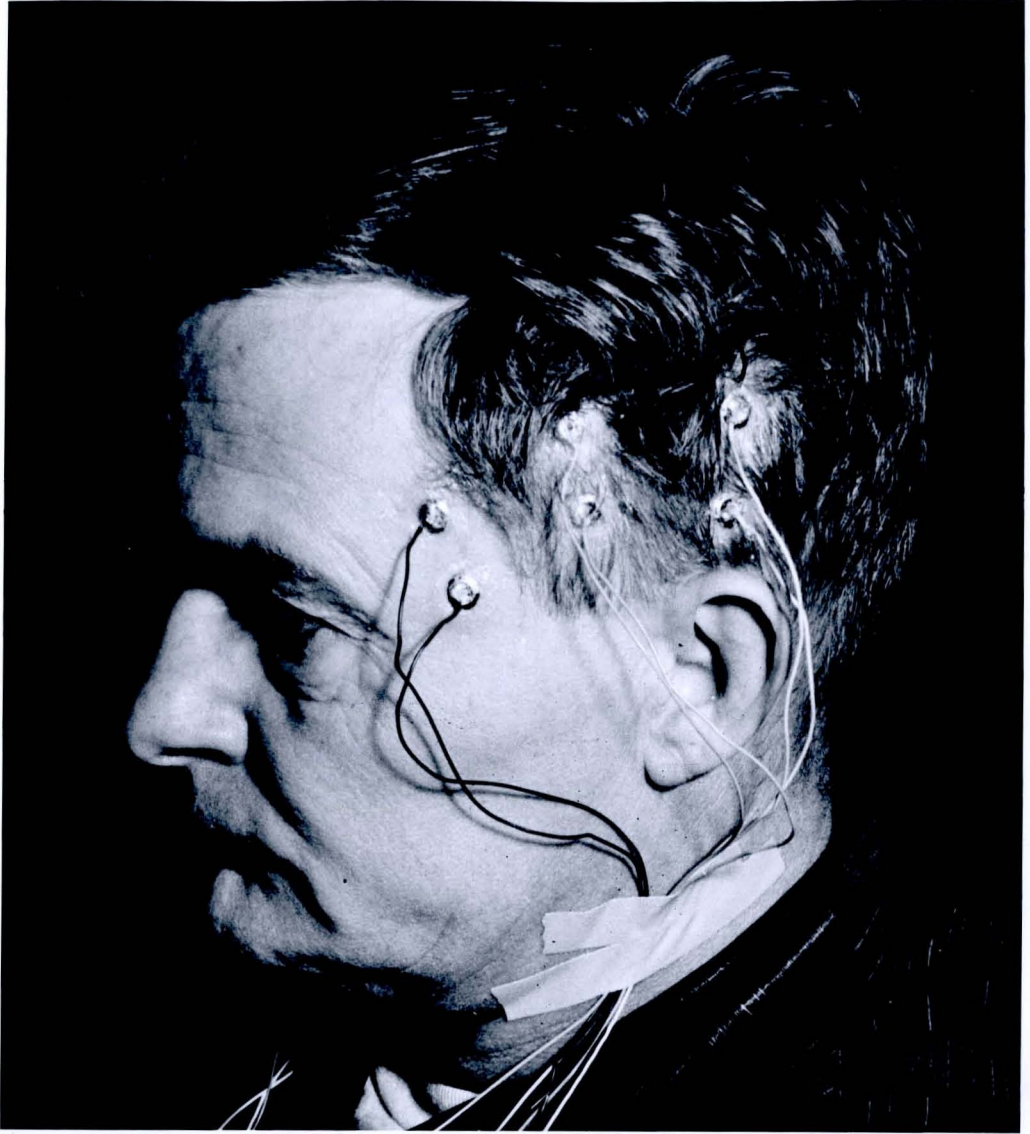


Figure 1

Figure 2

**Injecting electrode jelly under the attached electrode
with a syringe.**



Figure 2

Figure 3

Ohmmeter used for testing skin resistance.



Figure 3

Figure 4

Subject seated in the Faraday cage showing:

- A. Electrode terminal box.
- B. Mirror on the stand.
- C. Position of the subject.



Figure 4

Figure 5

A mirror with the horizontal line for head orientation.



Figure 5

Figure 6

The electromyograph equipment showing:

- A. Power supply unit.
- B. Amplifier unit.
- C. Crystograph.
- D. Time base marker.

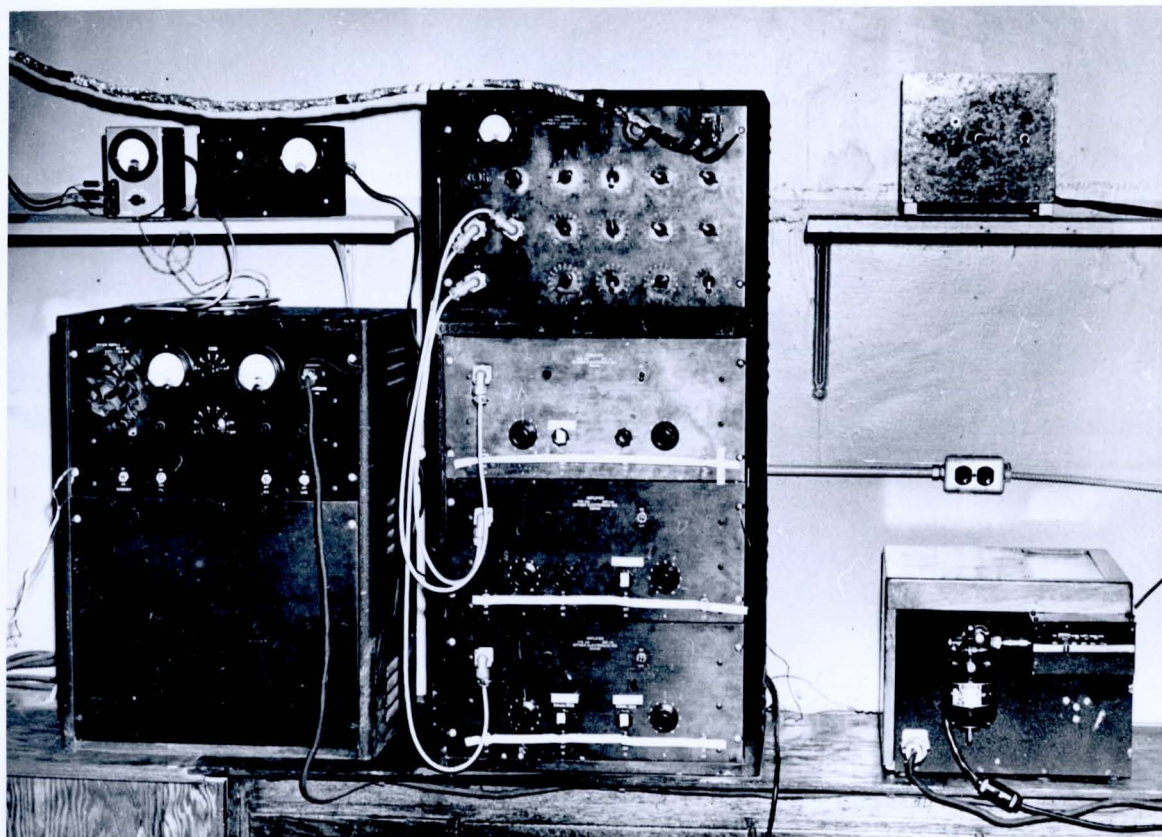


Figure 6

Figure 7

Crystograph with a pen for time base marker.

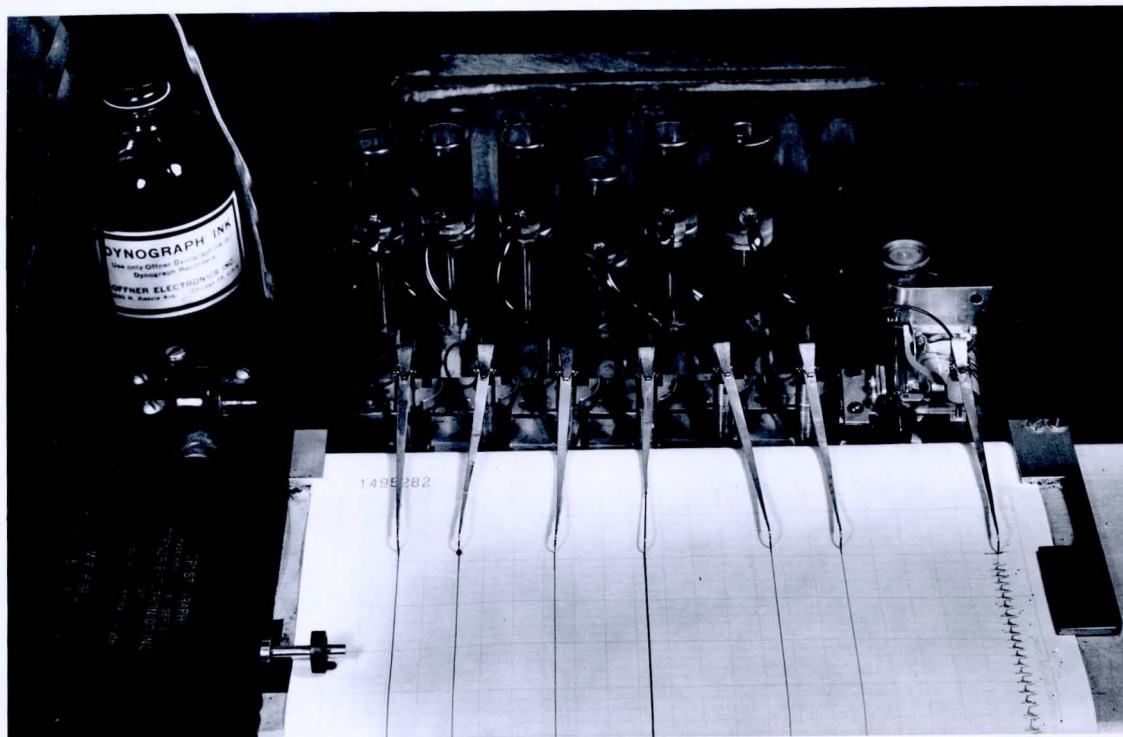


Figure 7

Figure 8

The cessation of activity and the onset of the rest period.

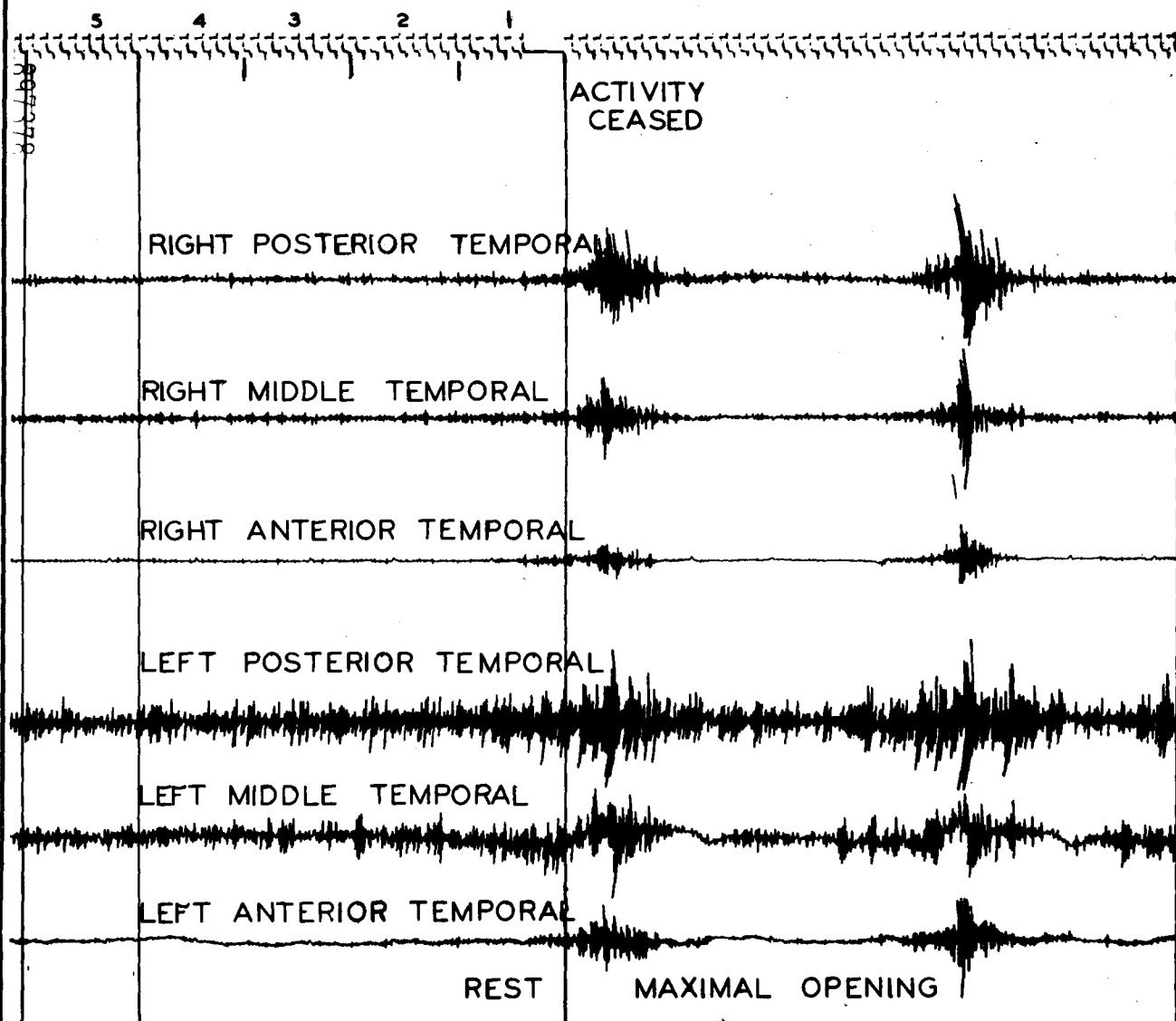


Figure 8

Figure 9

Sketch showing recorded one minute rest period divided into four equal parts, fifteen seconds each, and the random selection of one second period from each part.

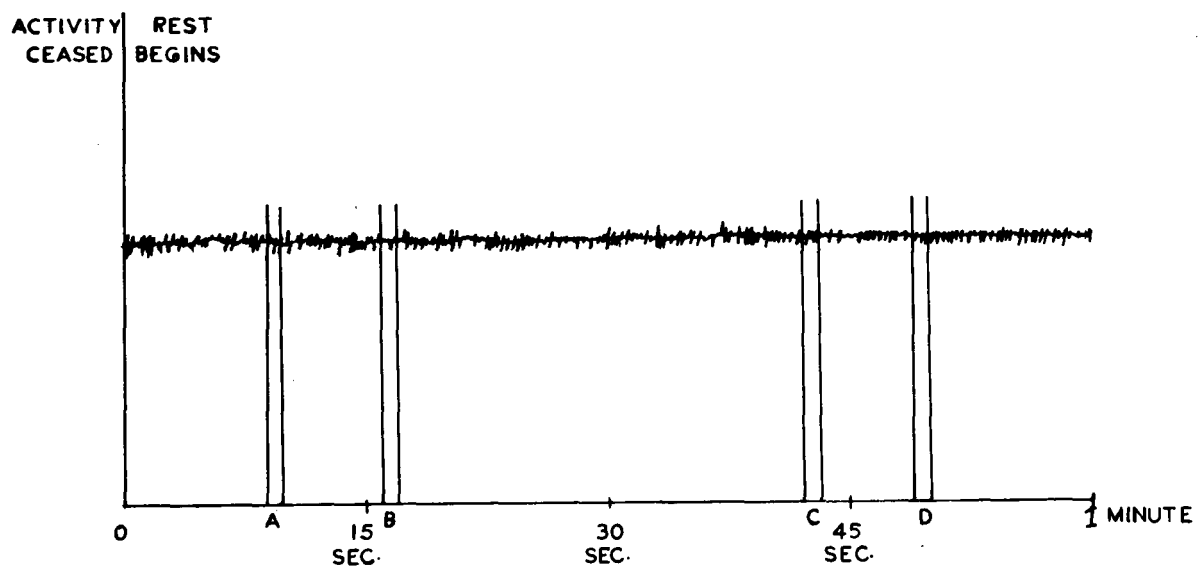


Figure 9

Figure 10

Randomly selected one second period showing amplitude and frequency of waves measured for the statistical appraisal.

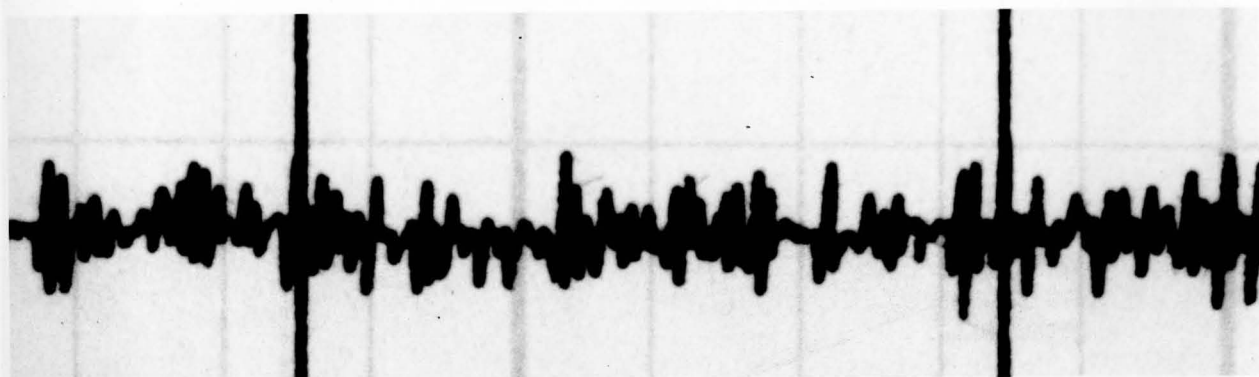


Figure 10

Figure 11

Vernier calipers, eye-piece with thirty-three times power of magnification and a scale.

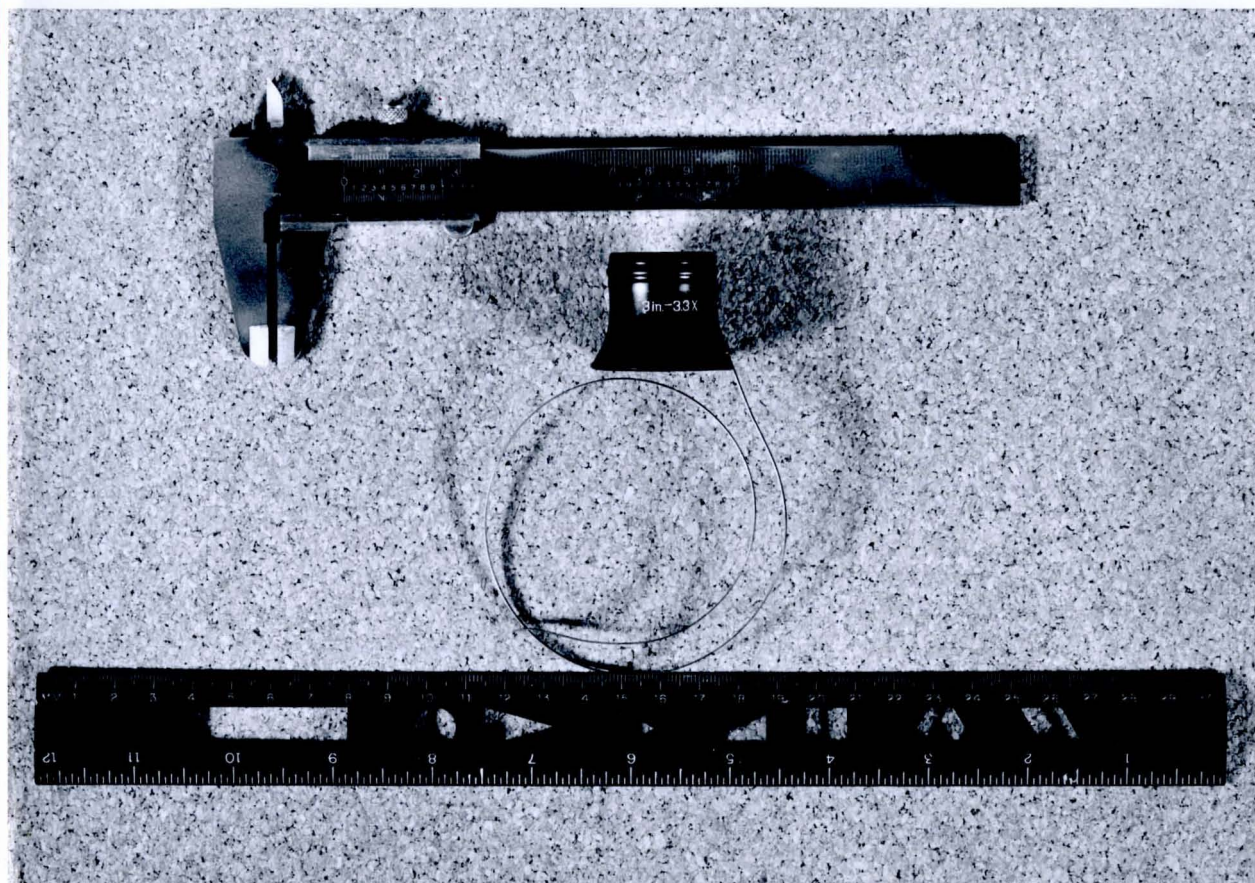


Figure 11

Figure 12

Callibration of ten microvolts input.

CHANNEL

F

E

D

C

B

A

CALIBRATION

IO_u INPUT

Figure 12

CHAPTER III

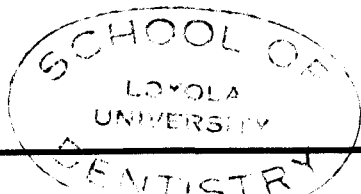
EXPERIMENTAL RESULTS

A. General Findings

Rest action potentials were recorded from the anterior, middle, and posterior fibers of the right and left temporal muscles of ten edentulous subjects. Four one-second tracings were used for the statistical analysis as described. The recorded data were reduced to microvolt-seconds as described. Since many zero readings were present and the data formed a skewed distribution, it was necessary to use the transformation. One unit was added to the microvolt-second and the square root of this total was used as the transformed data. Table II shows the results of the statistical analysis.

The components of variance for this design have shown that, since the "subjects" and the one-second "periods" were treated randomly, their mean squares were to be treated against the error mean square. The means squares of the "muscle groups", "sides", and "activities", which were 'fixed' sources, were to be treated against their respective interaction variances. The asterisks affixed to the variance ratio in Table II indicate the degree of significance at conventional levels.

The amount of residual activity recorded during mandibular rest varied greatly in different subjects (Fig. 15). In a subject, number nine, no



activity was recorded from the anterior and middle fibers although a low level activity, averaging about three microvolts at a frequency of about twenty waves per second, was recorded from the posterior fibers (Fig. 19, 20 and 21). This was the lowest amount of activity observed in any of the subjects, but it was definitely above the noise level of the recording apparatus. By way of contrast, the maximum activity was recorded from the posterior fibers of another subject, number three, as fifteen microvolts at a frequency of about fifty-five waves per second (Fig. 23).

There was the full range of activity shown between the several muscle groups which were studied. The anterior group showed no residual activity in many subjects while the posterior group always had some activity, and as mentioned above, this was the group which displayed the highest voltages which were recorded in the whole study. The middle group of fibers showed some activity in all subjects except the one mentioned above, but the highest value observed as about ten microvolts at a frequency of about fifty waves per second.

Figure 13 shows the graphical comparison of the average energy output per second at rest of all muscle groups following three exercises. Figure 13 also shows the average energy output of each muscle group at rest following the different exercises. Figure 14 shows the average energy output per second of all muscle groups during rest at different time periods following cessation of the exercise. Figure 15 shows that there is no relation between the age of

the subject and the energy output by their temporal muscles during rest. Table I shows name of the subjects, their age, approximate length of time they were edentulous, and average energy output per second by the temporal muscles.

The following is the summary of the residual activity after different exercises:

B. Residual Activity after the Exercise of Saying "Mississippi"

Action potentials recorded during mandibular rest after this exercise were lower in amplitude in most of the patients studied. In subject number nine, the temporal muscles were almost relaxed except few bursts of spontaneous hyperactivity (Fig. 19). In subject number six, the right temporal muscle showed no activity except a few bursts from what appeared to be single motor unit potentials. There were about twelve of these diphasic discharges recorded from the posterior fibers. These ceased in twelve seconds. The left middle fibers showed a typical single motor unit activity amounting to fifteen per second.

On the other hand, greater activity was recorded for the same muscle from subject number three (Fig. 22). The anterior and middle fibers of the left temporal muscle recorded the activity six and nine microvolts respectively with the frequency of fifty-seven and forty-seven waves per second respectively. These fibers of right side elicited the activity ranging in the neighborhood

of four microvolts with the frequency of forty-five waves per second. The posterior fibers in this subject had the activity with little more frequency but little less amplitude than the left posterior fibers. However, the average amplitude of these posterior fibers was twelve microvolts and the average frequency was sixty waves per second.

Similar activity but with less frequency was also recorded from the left posterior fibers in subject number one. Right posterior fibers showed the activity of 6.5 microvolt amplitude. The activity recorded from the left anterior and middle fibers in this subject was very similar to those recorded in subject number three. But practically no activity was shown by the right anterior and middle fibers. The rest of the subjects showed residual activity of low amplitude. All these subjects showed more activity in the left temporal muscle except one who showed more activity in the right temporal muscle.

The residual activity was present throughout the one-minute period. There was no complete relaxation nor was there an interruption in activity between the cessation of this exercise and the onset of the residual activity. The residual activity decreased in amplitude for the first forty-five to fifty seconds after its onset, and then it either increased a little or remained at about the same amplitude. There was very little change in frequency. At no time had this activity completely ceased except once as mentioned above.

C. Residual Activity after the Exercise of Swallowing:

The residual activity at rest recorded after this exercise was more than that recorded after the exercise of saying "Mississippi". Six subjects showed no activity in the right anterior fibers except few bursts throughout the rest period. Two subjects showed sustained activity whereas the other two subjects showed irregular activity of high and low amplitude. The left anterior fibers showed no activity in four subjects. In three subjects these fibers showed low voltage activity, one of which had very high frequency of fifty waves per second. A subject number five was very active with frequency of thirty-three waves per second in these fibers, in two out of five consecutive records. The activity decreased to zero towards the end of one minute period. In other three records these fibers showed no residual activity. The remaining two subjects showed the activity of four microvolts with the frequency of forty waves per second.

The right middle fibers in subject number nine showed no activity (Fig. 20), whereas his left middle fibers showed low activity at the beginning of the rest period, and it continued to decrease to zero in the next few seconds. In subject number ten the left middle fibers showed low amplitude activity with the frequency of about ten waves per second, but they were completely relaxed by the end of one minute period and the residual activity had ceased. The right middle fibers in this subject showed no activity

except few bursts here and there. Two subjects had high activity of six microvolts amplitude with the frequency of forty waves per second in the left middle fibers, whereas their right middle fibers had lower activity with the same frequency.

The remaining six subjects had an average amplitude of three to four microvolts with the frequency of twenty to thirty-five waves per second in the middle fibers. Three out of these six subjects had low voltage activity with low frequency in the right middle fibers, two subjects had low voltage activity but high frequency of forty-five waves per second, and one had low voltage activity decreasing progressively to zero in thirty seconds in three out of five records. The other two records showed the activity of low amplitude with the frequency of twenty-two waves per second.

All subjects had continuous but decreasing residual activity in posterior fibers all throughout the one minute period during which the activity was appraised, except one subject, number nine, whose posterior fibers quieted down within thirty seconds after swallowing (Fig. 20). During first thirty seconds these fibers showed low activity of five or six waves per second. In subject number seven the activity in both groups of posterior fibers was similar to that in the middle fibers. Similarly, the activity in the left posterior fibers was the same as that in the left middle fibers in subject number six, and the activity in the right posterior fibers was the same as

that in the right middle fibers in subject number ten. In one subject, number one, an irregular pattern of alternately high and low voltage activity was observed in the right posterior fibers (Fig. 25). The remaining subjects showed the activity of eight to ten microvolts with the frequency of thirty-five to forty waves per second.

D. Residual Activity after the Exercise of Maximal Opening

The residual activity recorded during mandibular rest after this exercise showed similar results to those shown after the exercise of swallowing. The anterior and middle fibers showed more activity here than after the exercise of swallowing, but the posterior fibers in these subjects showed less activity here than after the exercise of swallowing (Fig. 13).

Unlike the results observed after the other exercises, here the anterior fibers were active in all subjects except in two instances where the right anterior fibers were silent. The left anterior fibers showed some activity even in subject number nine which was not seen at rest after other two exercises. The activity in anterior fibers was low in voltage except in two subjects, numbers three and one, where the activity recorded from the left anterior fibers had average four to five microvolt amplitude.

In subject number seven the middle fibers were more active than the posterior fibers, so also in subject number nine where the left middle fibers were more active than the left posterior fibers (Fig. 21). The right

posterior fibers were more active than the right middle fibers. In all other subjects the posterior fibers were more active than the middle fibers. Only three subjects had the left middle fibers showing more activity than the right middle fibers, while the other two subjects showed similar activity in the middle fibers of both sides. The posterior fibers in subject number nine showed very little or no activity (Fig. 21). The right posterior fibers in subjects numbers five and six had more activity than the left posterior fibers, while in all other subjects the left posterior fibers were more active. Subject number one had similar activity of alternate high and low voltage in right temporal muscle as was seen after the exercise of swallowing (Fig. 25). His left posterior fibers had activity of average fifteen microvolts with the frequency of sixty waves per second.

Figure 13

Graph showing average microvolt-seconds at rest after different exercises.

- o - Average microvolt-seconds recorded from the right and left temporal muscles.
- x - Average microvolt-seconds recorded from the anterior fibers of the temporal muscles of both sides.
- o - Average microvolt-seconds recorded from the middle fibers of the temporal muscles of both sides.
- - Average microvolt-seconds recorded from the posterior fibers of the temporal muscles of both sides.

Figure 14

Graph showing average microvolt-seconds from the temporal muscles during one minute period.

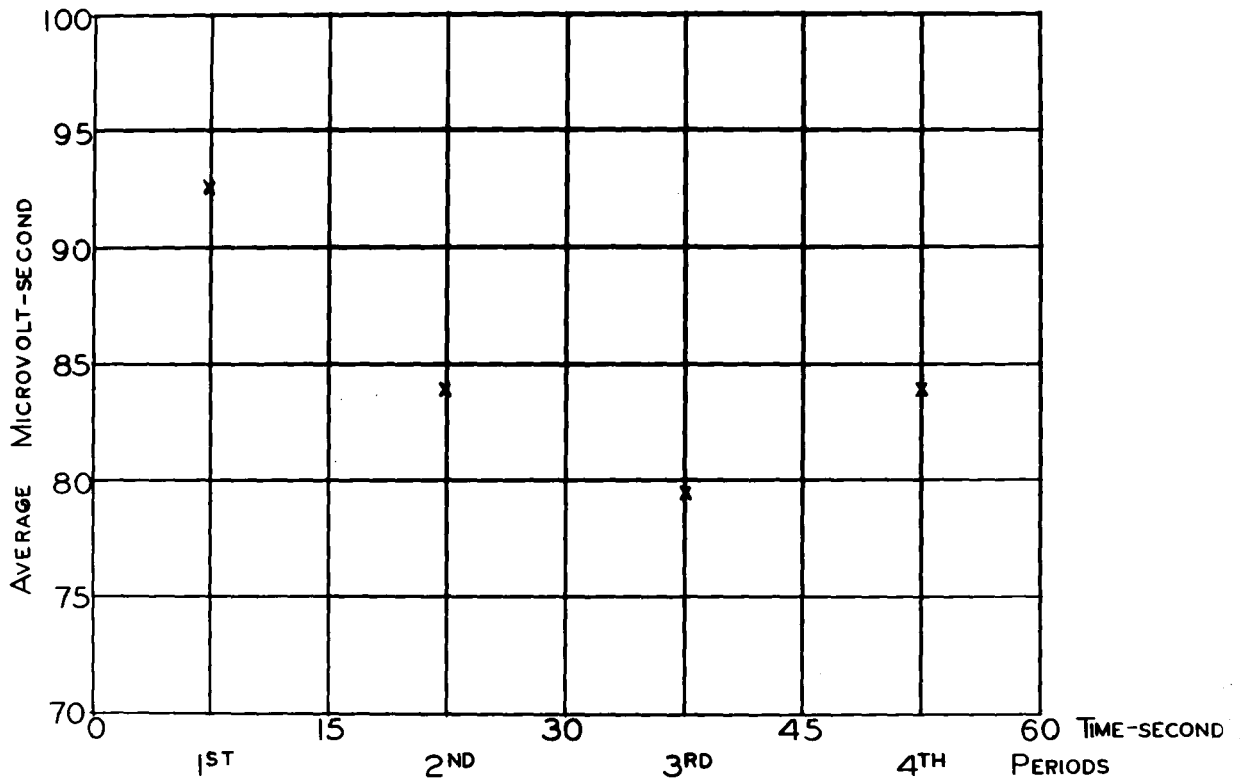


Figure 14

Figure 15

Graph showing the variation between the average microvolt-seconds recorded from each subject and their age. Note the variation between the subjects.

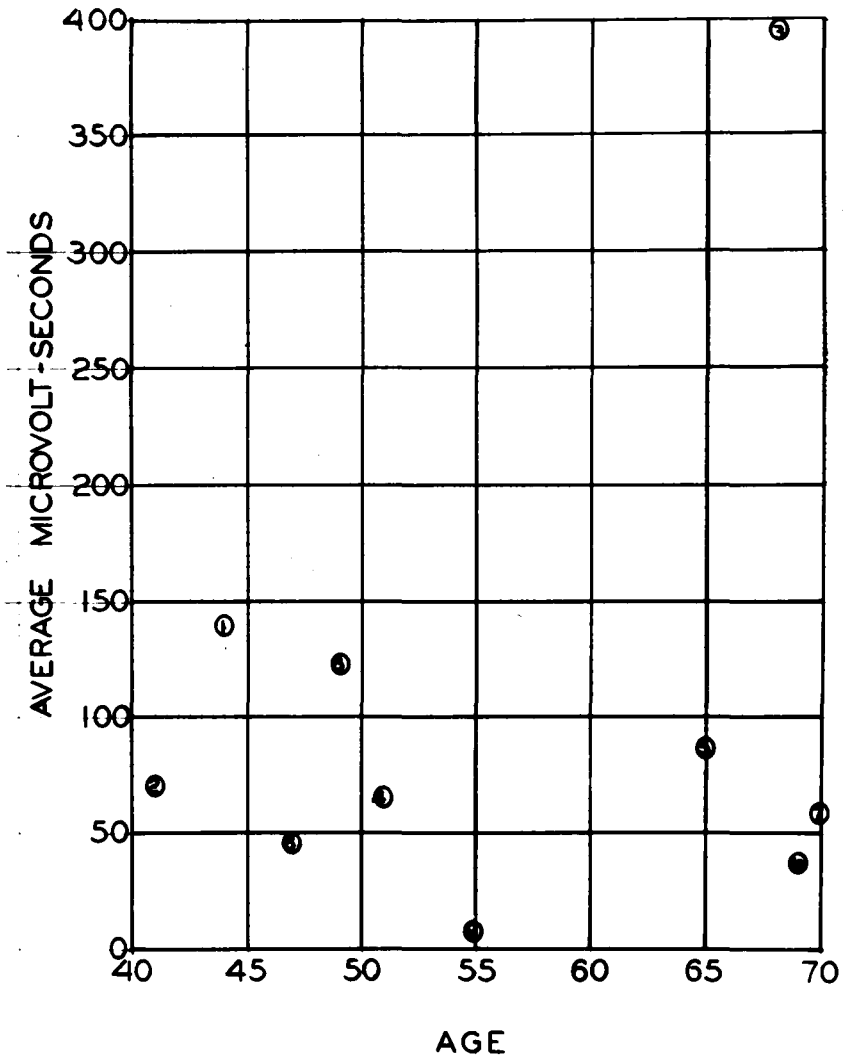


Figure 15

Figure 16

Electromyograph record of subject number eight showing the residual activity from the anterior, middle, and posterior fibers of the right and left temporal muscles at mandibular rest after the exercise of saying "Mississippi".

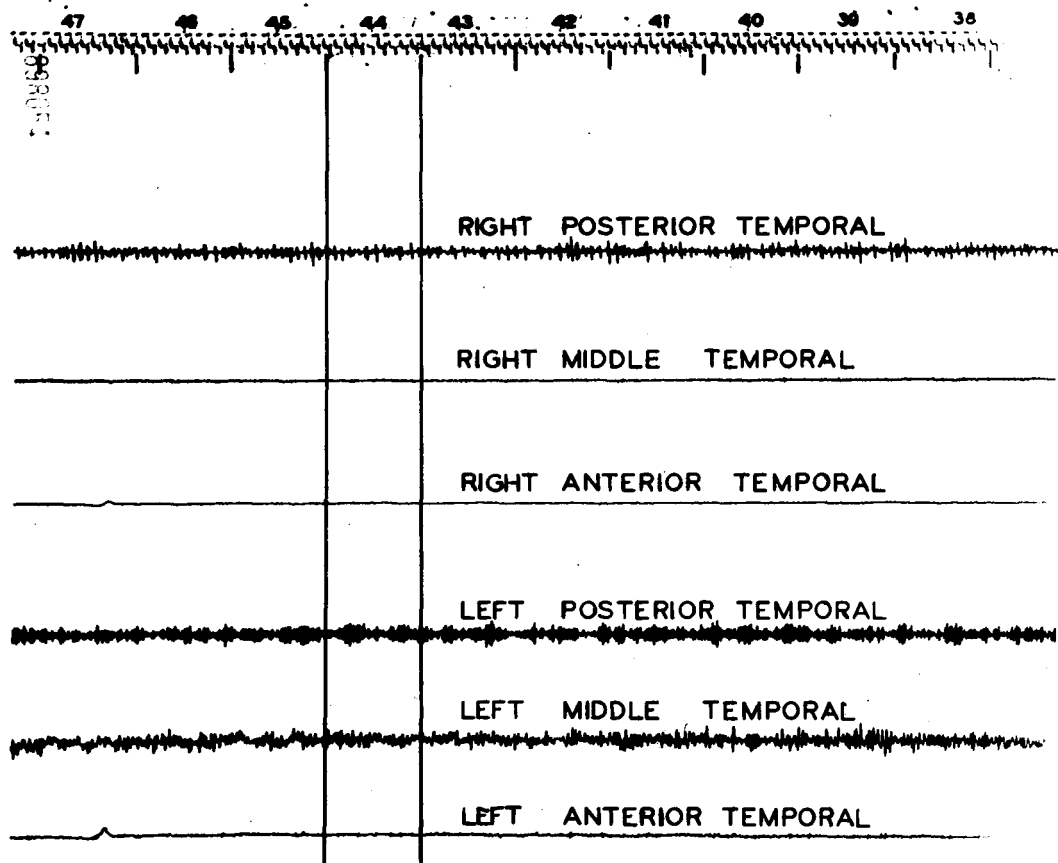


Figure 16

Figure 17

Electromyograph record of subject number eight showing the residual activity from the anterior, middle, and posterior fibers of the right and left temporal muscles at mandibular rest after the exercise of swallowing.

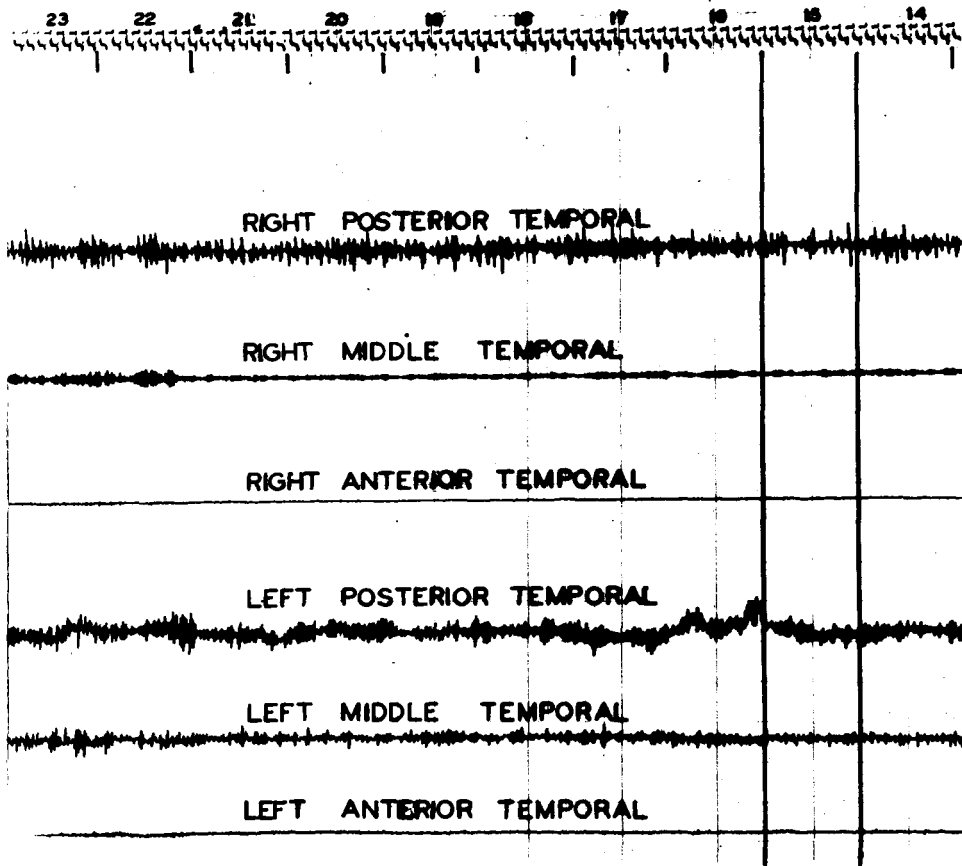


Figure 17

Figure 18

Electromyograph record of subject number eight showing the residual activity from the anterior, middle, and posterior fibers of the right and left temporal muscles at mandibular rest after the exercise of maximal opening.

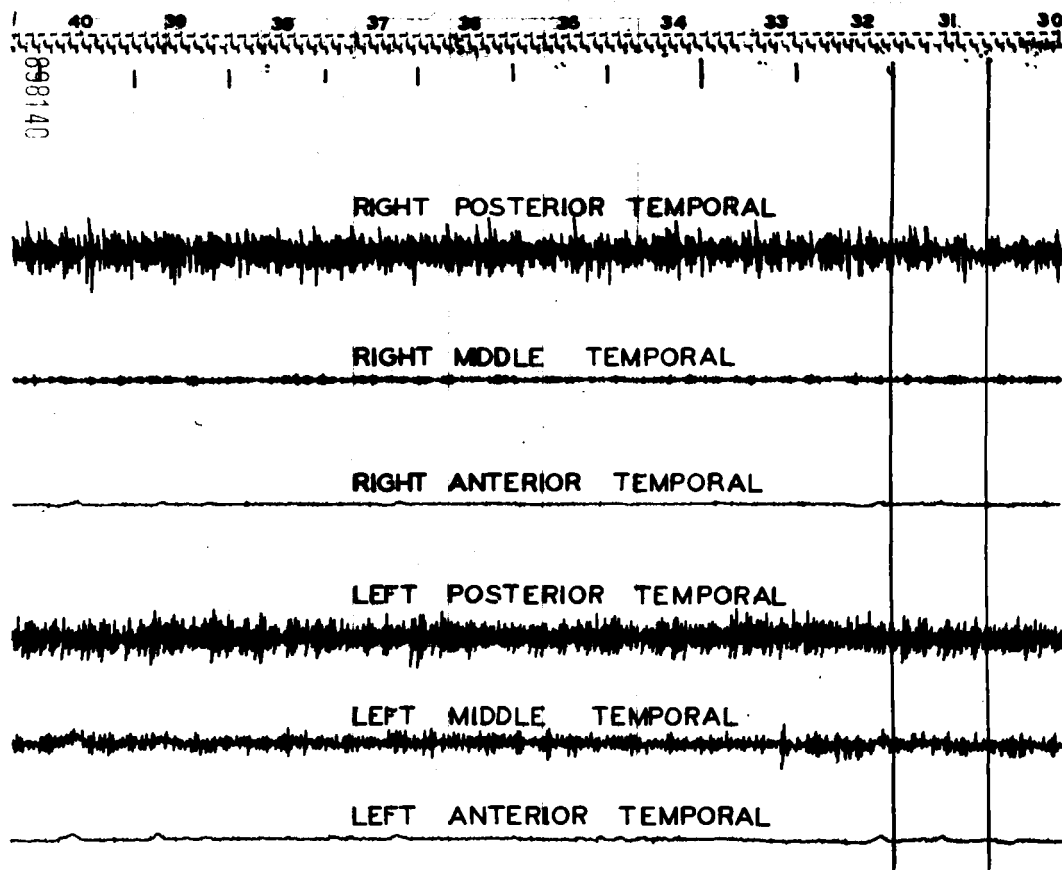


Figure 18

Figure 19

Electromyograph record of subject number nine showing the residual activity from the anterior, middle, and posterior fibers of the right and left temporal muscles at mandibular rest after the exercise of saying "Mississippi".

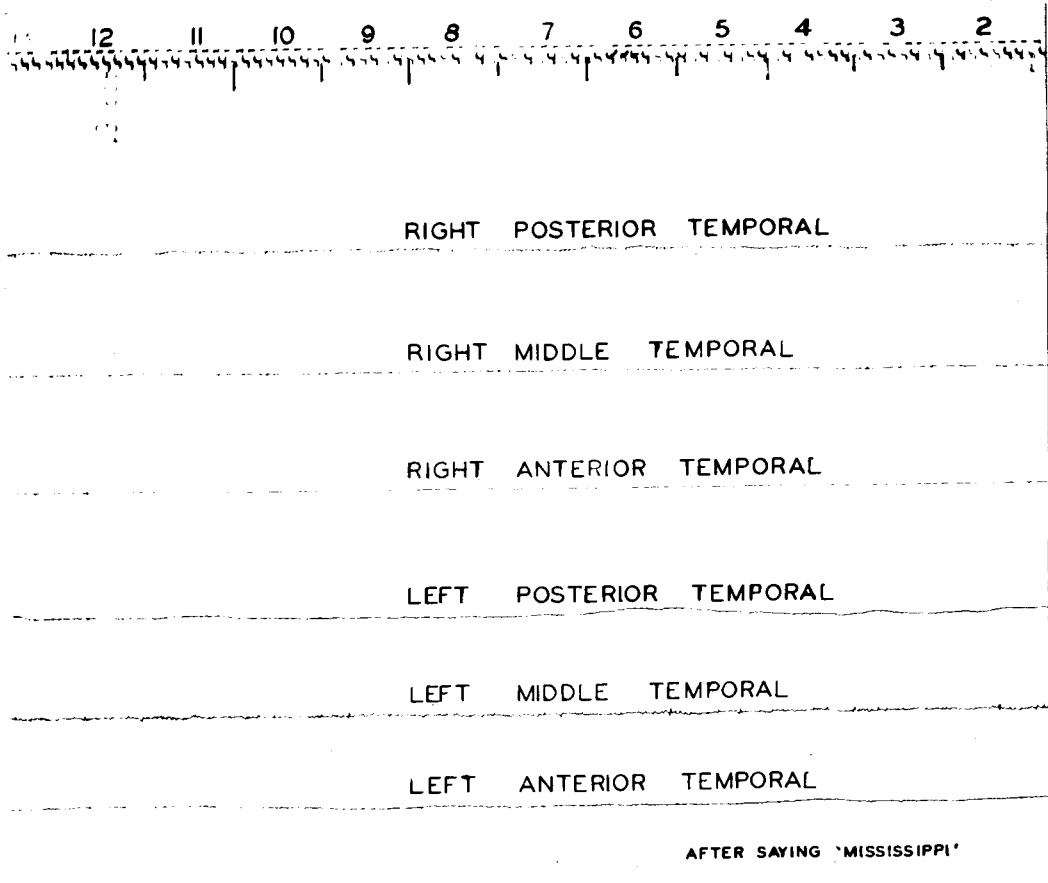


Figure 19

Figure 20

Electromyograph record of subject number nine showing the residual activity from the anterior, middle, and posterior fibers of the right and left temporal muscles at mandibular rest after the exercise of swallowing.

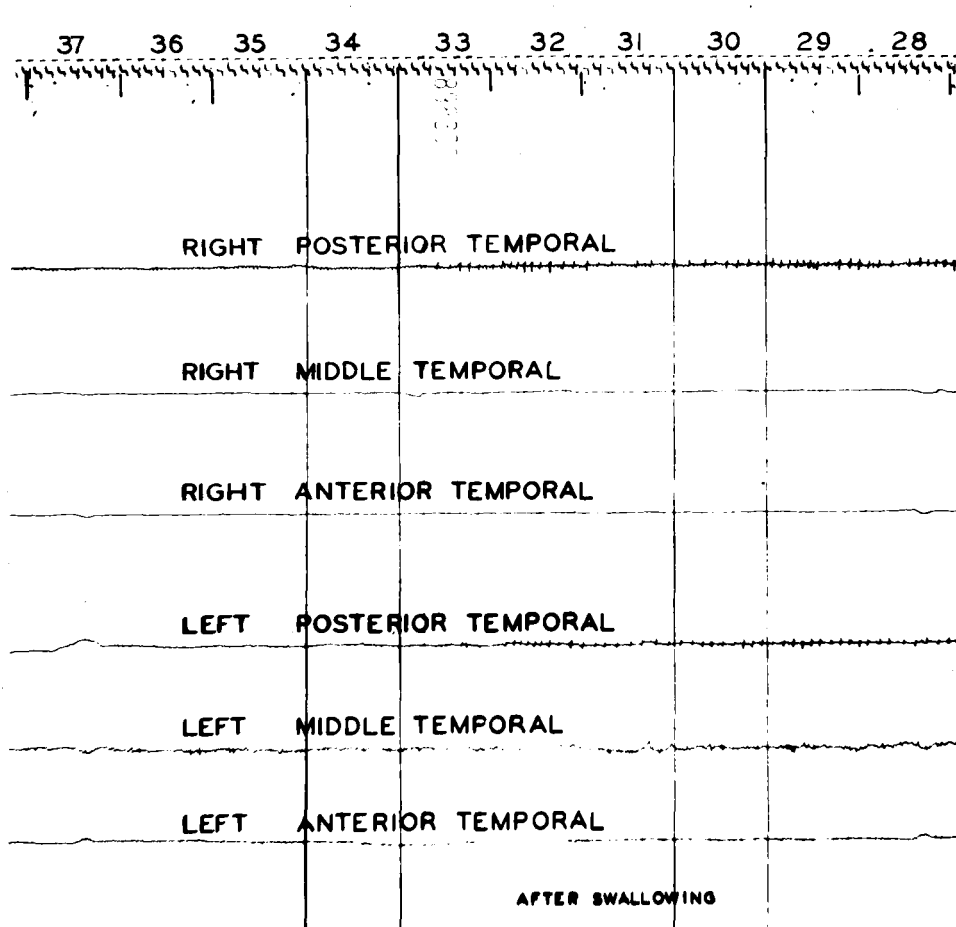


Figure 20

Figure 21

Electromyograph record of subject number nine showing the residual activity from the anterior, middle, and posterior fibers of the right and left temporal muscles at mandibular rest after the exercise of maximal opening.

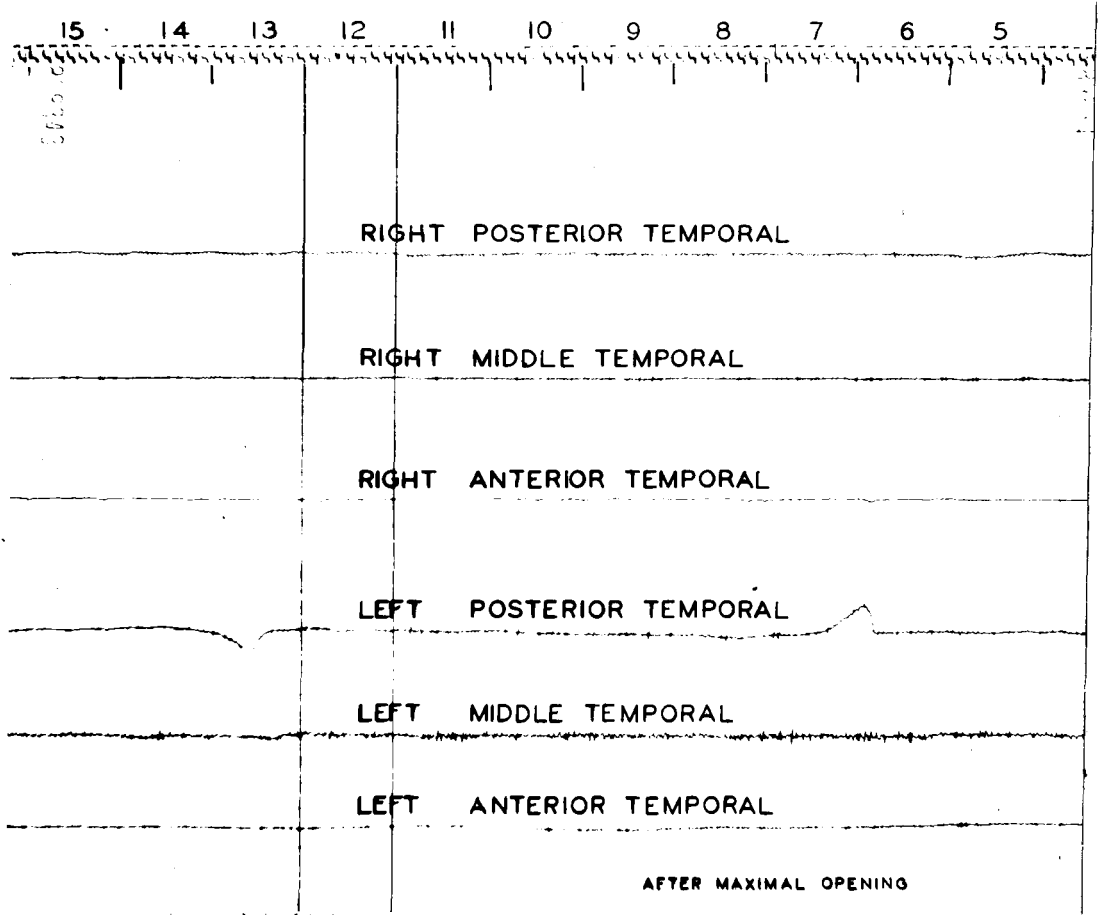
**Figure 21**

Figure 22

Electromyograph record of subject number three showing the residual activity from the anterior, middle, and posterior fibers of the right and left temporal muscles at mandibular rest after the exercise of saying "Mississippi".

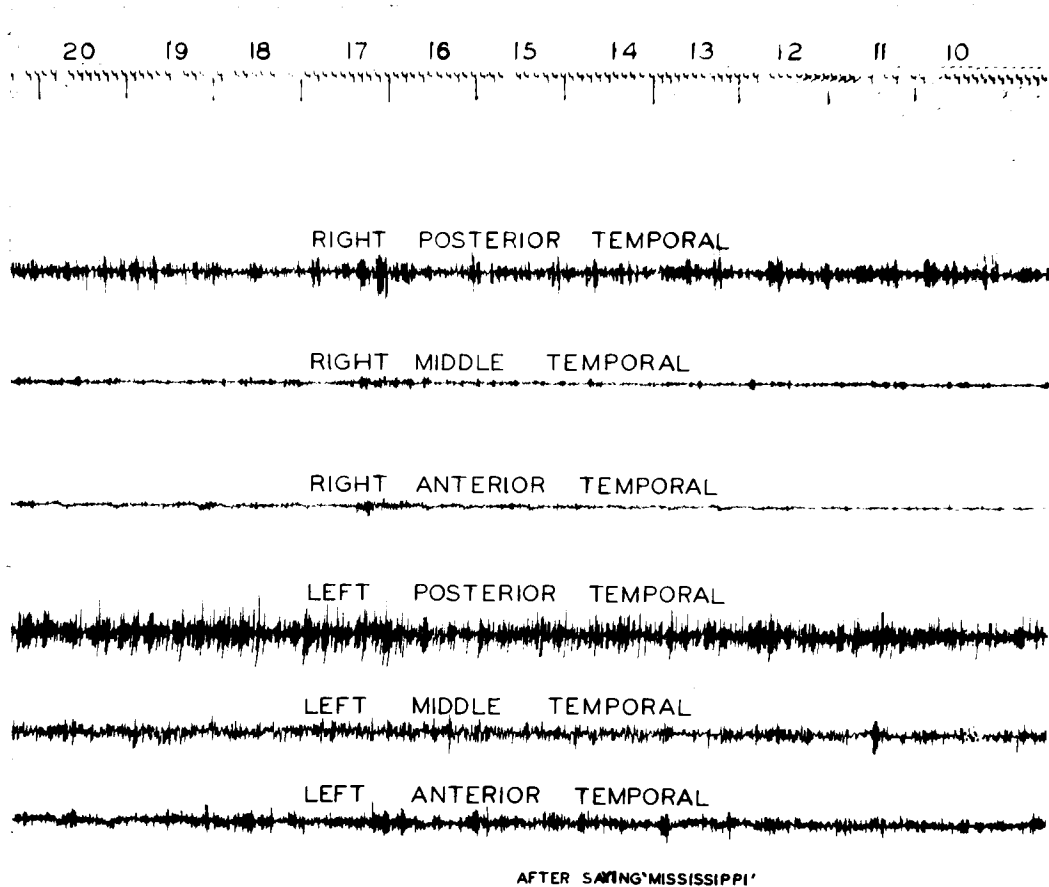


Figure 22

Figure 23

Electromyograph record of subject number three showing the residual activity from the anterior, middle, and posterior fibers of the right and left temporal muscles at mandibular rest after the exercise of swallowing.

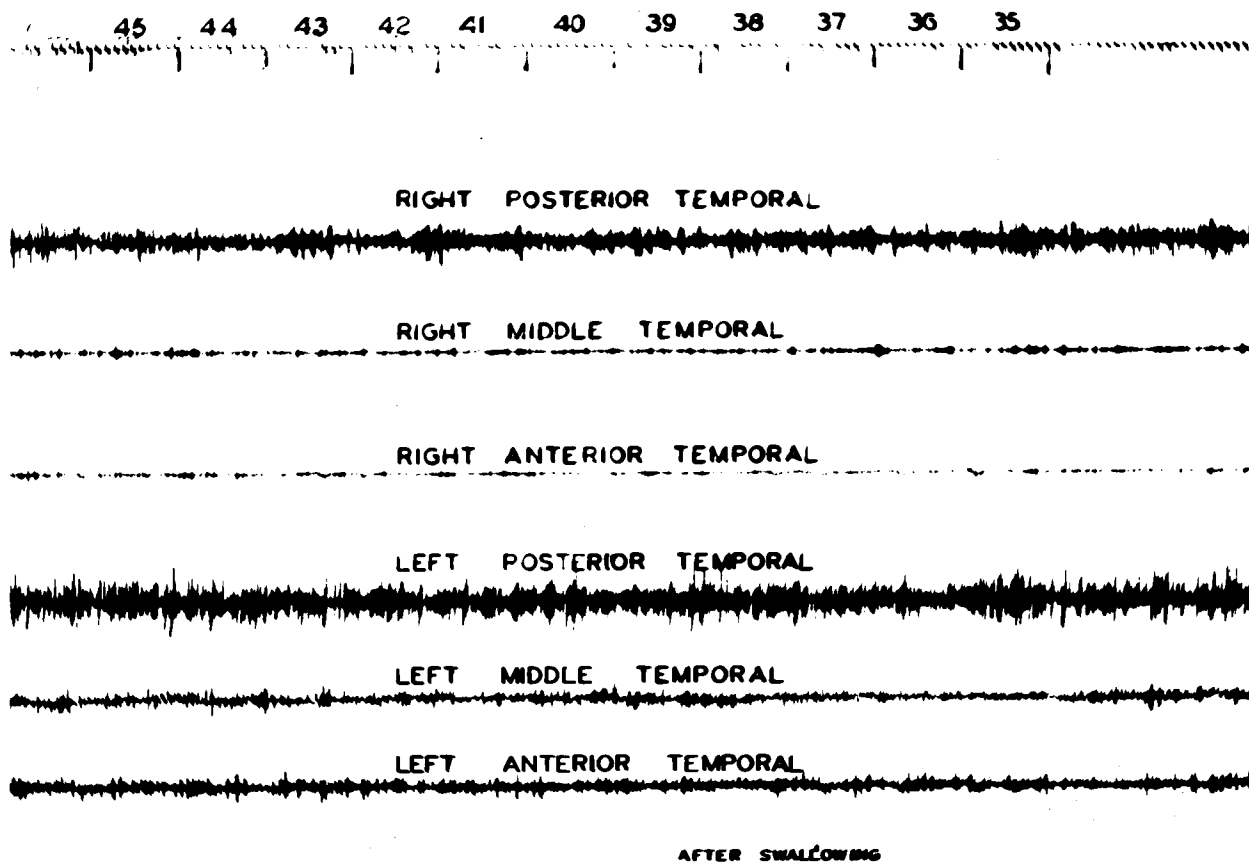


Figure 23

Figure 24

Electromyograph record of subject number three showing the residual activity from the anterior, middle, and posterior fibers of the right and left temporal muscles at mandibular rest after the exercise of maximal opening.

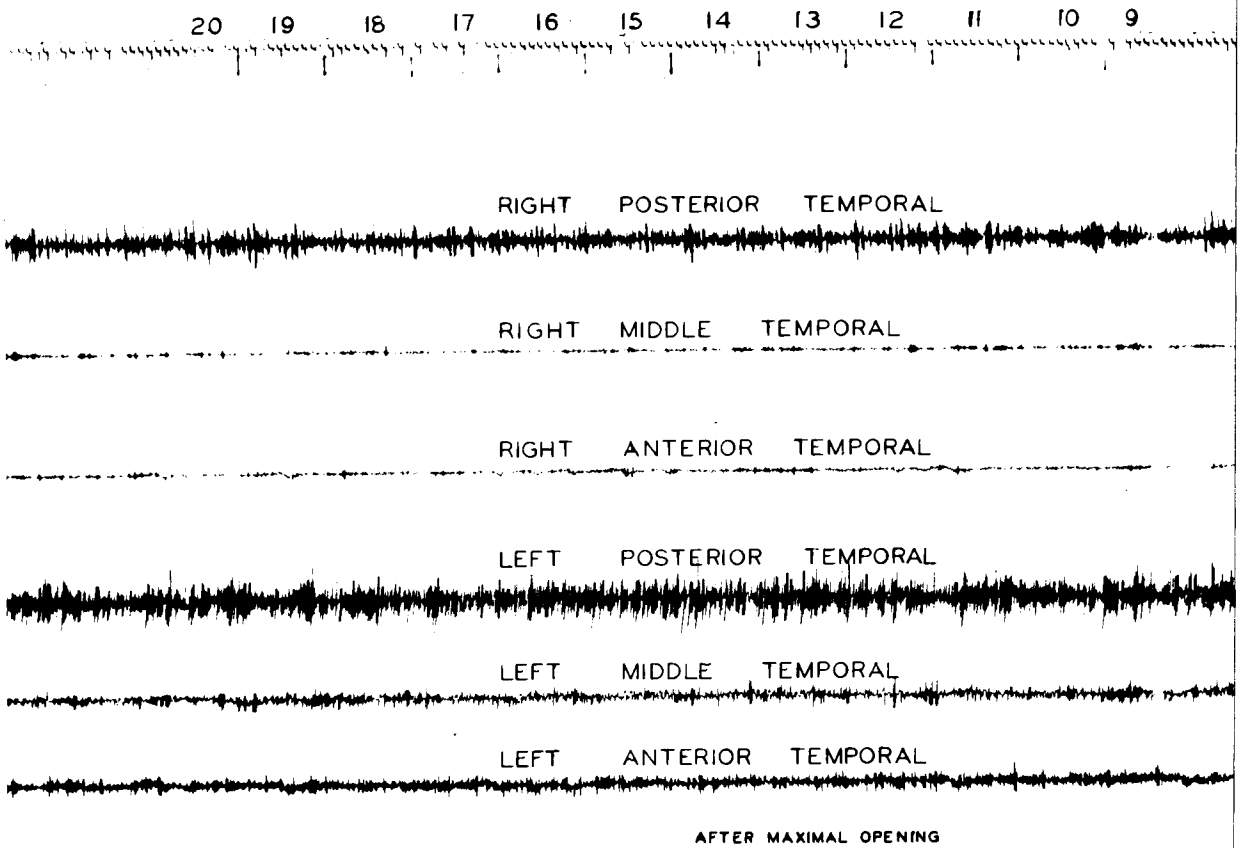


Figure 2h

Figure 25

Alternate high and low voltage activity in the middle and posterior fibers of the right temporal muscle from the subject number one.

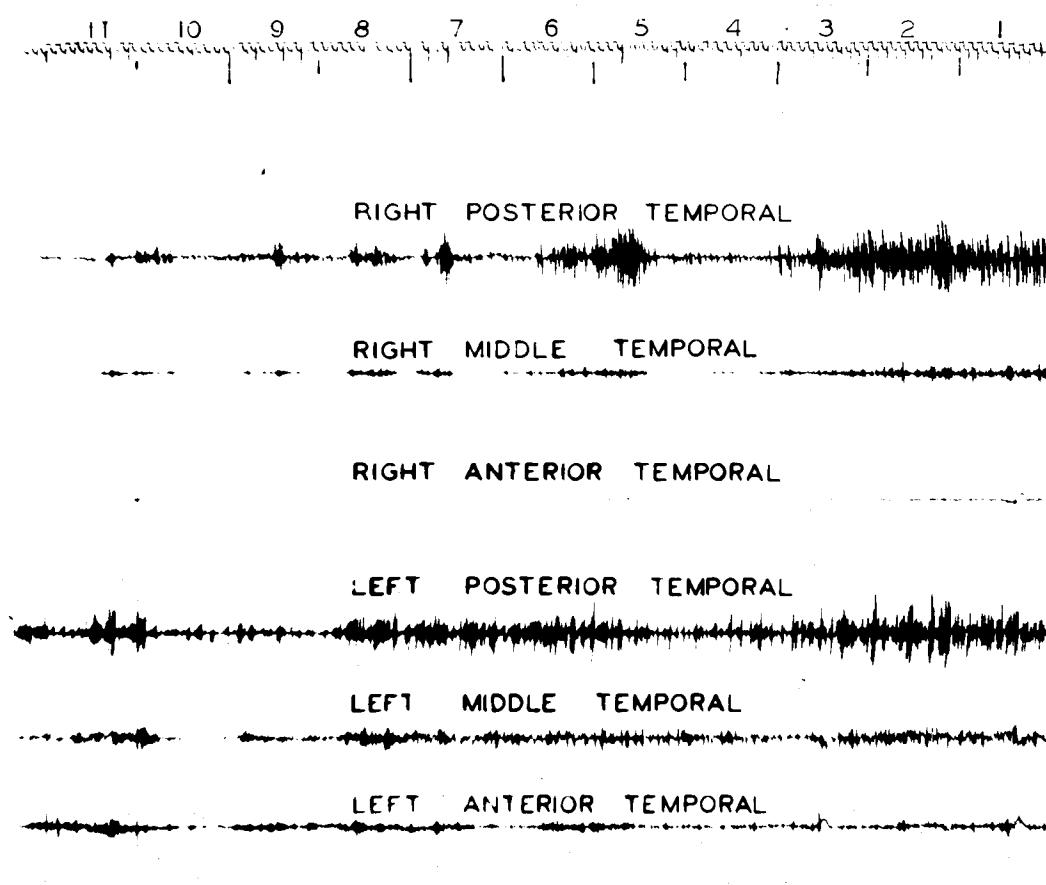


Figure 25

Figure 26

Illustration of the sensitivity of the electromyograph equipment. Note: A straight line recorded by the crystograph pen up to the gain eight and pen deflection due to high cycle amplifier noise at gain ten.

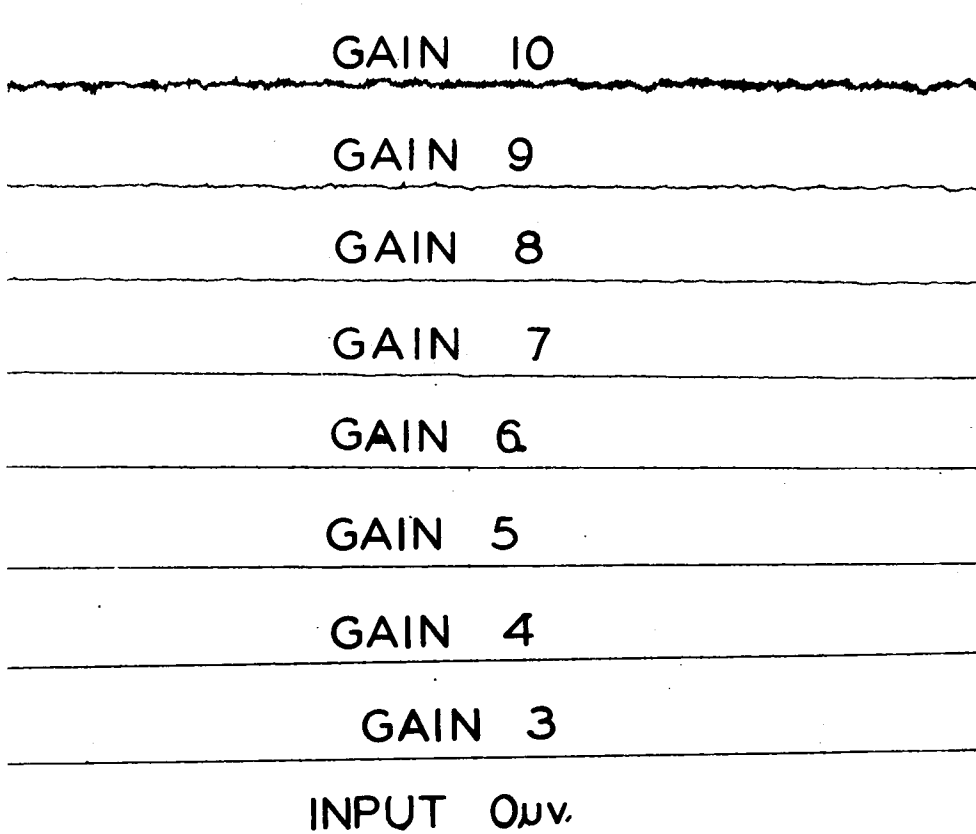


Figure 26

CHAPTER IV

DISCUSSION

The past literature in physiology has shown that there is no activity in a relaxed muscle. Adrian and Bronk (1929), Smith (1934), Lindsley (1935), Hoefer and Putnam (1939), and Weddell, Feinstein and Pattle (1944) have worked on various muscles of the body, e.g., triceps, biceps, deltoid, brachio-radialis, rectus femoris, vastus lateralis, sartorius, gastrocnemius, tibialis anticus, and other trunk, abdominal and neck muscles. They did not record any electrical activity when these muscles were at rest.

On the other hand, some investigators recorded some electrical potentials from the postural muscles at rest. Gilson and Mills (1941), Bosma and Gellhorn (1946), Joseph, Nightingale and Williams (1955), and others have studied the activity of several postural muscles at rest and recorded minimum activity. Since these antigravity muscles maintain the posture of the body, they exert little more tension than the other resting skeletal muscles. This activity is referred to as "tonus" or "minimum muscular activity".

Kelton and Wright (1949) also studied various postural muscles of the leg and mandible (masseter and anterior fibers of the temporal muscles) and found that they were electrically silent, except tibialis anterior and soleus muscles which showed little activity. Dental literature also shows

similar results from the postural muscles of the mandible. Moyers (1950), MacDougall and Andrew (1953), Ballard (1955), Latif (1957), Javois (1956), Mullen (1956), Lemmie, Perry and Crumm (1958), Jensen (1959), and Garnick (1959) studied the temporal muscles at rest. They all recorded the minimum muscular activity from this muscle.

This study corroborates and elaborates on the findings of Jarabak (1957). He recorded hyperactivity from the temporal muscles at rest in edentulous subjects. He also observed that this activity decreased after onset. Lemmie, Perry and Crumm (1958) recorded the minimum muscular activity from temporal muscles at rest in edentulous subjects, but they did not mention the nature of this activity. Jensen (1959) recorded similar minimum muscular activity from the temporal muscles which was constant.

In the present study residual activity was recorded from the temporal muscles at mandibular rest in edentulous subjects. The activity was found to be decreasing for about twenty-five seconds after its onset. Jarabak did not record any such activity in the control group having full complements of natural teeth. The author did not have a control group because his experiment was designed to study the onset, magnitude, duration and frequency of residual activity in edentulous subjects. Kelton and Wright (1949) did not record any residual activity from the anterior fibers of the temporal muscles, but they did not state the dental conditions of their subjects nor did they state at what level of sensitivity their instrument recorded.

Moyers (1950), and MacDougall and Andrew (1953) recorded low level activity from the temporal muscles in normal individuals which was constant. Javois (1956) and Mullen (1956), maintaining the head in a cephalostat, recorded low level activity from the temporal muscles. In our study the cephalostat was not used to orient the head because the subjects became more apprehensive and conscious of the situation, causing increase in subjective variation. Ballard (1955) suggested that there may be a change in the pattern of activity if the individual's head is clamped in a cephalostat. Jensen (1959) found no significant difference between the results obtained with the head and mandible in their natural position or when oriented in a cephalostat. The use of a mirror in our study (Fig. 5) helped maintain the natural position of the head, and orient it on the Frankfort horizontal plane. This eliminated the stretched position usually associated with head fixation in the cephalostat.

Garnick (1959) observed a wide range for the temporal muscles during which least activity was recorded. This range extends from the wide opening of the mouth to the light occlusal contact of the teeth. When teeth came to light occlusal contact, the temporal muscles showed greater activity. It is true, as Sicher says, that the rest position of the mandible does not depend on the presence of teeth, but it is likely that the presence of teeth and their periodontal membranes would establish a memory pattern to guide the mandible to rest position. In edentulous individuals this memory pattern

is distorted because proprioceptors from the teeth are lost. Since the guidance from the teeth is lost, these edentulous individuals would have the tendency to overclose which causes contractions of the fibers of the temporal muscles. This increases the tension in the muscle proprioceptors which send impulses at a reflex level into the mesencephalic root to relax the muscle fibers and thus re-establish the resting mandibular muscle length.

Thus it would follow that activity in the temporal muscle decreases during this period. The postural position of the mandible is determined by the proprioceptors within muscles and temporomandibular joint. This also indicates that such residual activity is due to stimuli originating from the peripheral nervous system and is at a reflex level.

Most of the subjects in this study showed residual activity arising from the temporal muscles, similar to the fasciculations recorded by Denny-Brown and Pennybecker (1938) in patients of progressive muscular atrophy. These fasciculations are regular periodic discharges of single impulses of motor neurones. The disease usually attacks persons between the ages of forty-five and fifty years, but it may also attack older persons. Although the residual activity seen in experiment conducted for the present study bears resemblance to that reported by Denny-Brown and Pennybecker, the histories given by subjects used in this experiment did not reveal other symptoms needed to confirm progressive muscular atrophy. Although some of these subjects were senile and geriatric neurological and muscular changes have

set in on a subclinical level, it is still conceivable in the light of earlier works (Jarabak, 1957, Lemmie, Perry and Grumm, 1958) this activity is associated with the loss of proprioception arising from the teeth rather than from some neurological source.

Temporal muscles are the elevators of the mandible. One of their functions is to maintain the mandibular posture at rest against the gravitational force. This develops a certain amount of tension in the fibers of this muscle which is called "tonus". The tonus of muscle is fairly constant so long as the muscle exists in a fairly constant environment, but it will vary slightly with a change in conditions, such as blood pressure (rising or falling), body metabolism, nutrition, aging, acute or chronic illnesses, etc.

Since all subjects in this study were edentulous and had difficulty in chewing, and since they all were above the age of forty, there would be some change in muscle tone despite their seemingly sound physical condition. But there could not be any noticeable change in tonicity during the brief period when these electromyographic records were taken, thus indicating this residual activity could not possibly be due to change in muscle tonicity.

Each exercise in this experiment was repeated ten times before the mandible came to rest; this would invariably fatigue the temporal muscles, especially during the exercise of "maximal opening" when most of the motor units were functioning. Whenever a muscle is fatigued, it undergoes

fasciculation which lasts even after the muscle relaxes. These fasciculations due to fatigue are small bursts of contractions in a fasciculus and are due to irregular discharges of nerve. The discharges progressively spread to all nerve bundles in the fasciculus. These fasciculations may be tonic spasms wherein a muscle contracts more or less energetically without the conscious intention of the individual. The disturbance in thinking and emotion, due to various reasons, may also cause the hyperactivity of the motor system through the pyramidal cells of the cortex; this would cause the irregular muscle contraction. It is doubtful, however, that the activity would bear likeness to the fasciculations seen in these experiments.

Mullen (1956) showed that if the sensitivity of the electromyograph be kept between the gain one to four, it will not amplify the small action potential of minimum muscular activity large enough to be recorded. He used the sensitivity of gain ten because he could obtain the maximum pen deflection for the minimum muscular activity. Javois (1956) and Jensen (1959) also used the sensitivity of gain ten during their studies.

The electromyograph instrument used in the present study was found efficient at gain eight. When the electromyograph and crytograph were switched on without feeding any current through the amplifiers, pens recorded straight lines up to the gain eight after which, at gain nine, these pens became shaky (Fig. 26). At gain ten there was pen deflection even though no current was fed through the equipment. The base line irregularity was

due to the high cycle noise output of the amplifiers. Thus, gain eight was found efficient to record the minimum muscular activity and at the same time to avoid recording amplifier noise.

Subjects used in this study were all between the ages of forty and seventy years (Table I). The average voltage output per second obtained from the temporal muscles during rest in these subjects had no relation to their age (Fig. 15). Subjects age forty-four, forty-nine and sixty-eight years had greater average microvolt-second output than other subjects whose ages were fifty-five, sixty-nine and seventy years. One of the specific requirements in selecting the subjects for this study was that they should have had all their teeth extracted two months to a year prior to the testing. Table I shows that there was no relation between the average voltage output per second and the length of time these subjects were edentulous. This leads to the inference that spontaneous hyperactivity is also in no way related to the length of time the subjects were edentulous.

The anterior, middle and posterior fibers of the temporal muscles were studied to evaluate the function of these fibers during mandibular rest in edentulous subjects. This division was based on the direction of the various muscle fibers.

The analysis of variance has indicated a highly significant difference between the voltage output of these groups as shown in Table I. Figure 13 demonstrated that the energy output during the residual activity of these

fibers was directly proportional to their direction. The anterior fibers were vertical in direction and had the least energy output during the mandibular rest. The middle fibers (located posterior to the anterior fibers) became oblique in direction and yielded a greater energy output than the anterior fibers. The posterior fibers had the greatest energy output during rest, they took nearly a horizontal path from the origin to insertion.

This was in agreement with the findings of Latif (1957) who observed that posterior fibers were more active than the anterior fibers during mandibular rest, and with Moyers (1949) who found similar results in some patients with mandibular retroversion. The greater energy output obtained from the posterior fibers of the temporal muscles in this study also confirmed the clinical observation that the mandible is slightly retracted at rest in edentulous patients.

The residual activity at rest was recorded after performing three different exercises, i.e., saying "Mississippi", swallowing, and maximal opening. These exercises were selected on the basis of their practical use, since they are commonly used in establishing rest position during the construction of full denture prosthesis. This study revealed that the energy output during rest, after the exercise of saying "Mississippi", was little less than after the exercise of swallowing and maximal opening (Fig. 13). The anterior and middle fibers of the temporal muscle showed more residual activity during rest after the exercise of maximal opening than after the

exercise of swallowing. The posterior fibers showed more residual activity after the exercise of swallowing than after the exercise of maximal opening (Fig. 13).

An explanation would be as follows: The first few swallowings are done naturally without undue muscular strain, but additional swallowings become an effort and must be forced. This causes the power muscles e.g., the masseter muscles, to contract more vigorously while the mandible is being elevated for swallowing, and it also retracts the mandible slightly. The retraction, which causes more activity in the posterior fibers of the temporal muscles, does not happen during the repeated opening and closing movements of the mandible, at this time only the elevator muscles are functioning.

It is interesting to note that in this experiment the left temporal muscles showed more activity than the right in all subjects except one who had more active right temporal muscle than the left. In individuals having full complements of natural teeth the temporal muscles of both sides usually respond alike posturally. In this study a significant difference was found between the energy output of right and left temporal muscles (Table II). This indicated that the mandible deviated from the midline of the body, causing more activity in the temporal muscle of the side towards which it deviated.

It is difficult to attribute this mandibular deviation to any specific factor. There are, however, several conditions which may have led to the

deviation: (1) dental malocclusion, (2) an accommodative pattern of closure into centric due to the loss of some teeth and the shifting of others, (3) asymmetries in mandibular size, and (4) unilateral displacements.

Since accurate histories of the original denture conditions were not available, one can only speculate on the etiology underlying these mandibular deviations. This experiment documents many more disturbances in the normal opening and closing movements of the jaws than are described herein. It is unlikely for one to associate the deviations with muscular memory patterns. The automatic reflexes, as automatic movements are known, were reflexes which had to be reinforced for long periods of time to make them automatic. Assuming these reflexes were reinforced by the teeth, the reinforcement was lost when the teeth were lost. The question then is: If reinforcement ceases, when is the automatic reflex behavior lost to the memory? This experiment (that portion dealing with mandibular deviation) seems to indicate that the reflexes remain for some time because they seem to receive some reinforcement from the muscle, tendon, and temporomandibular joint sensory mechanisms.

The energy output from the temporal muscles during rest was not constant throughout one minute recordings. It was found that the residual activity decreased in amplitude and frequency for about forty-five to fifty seconds after its onset and then it either remained the same or increased slightly. These findings indicate that there is some tension developed in the muscle

and tendon proprioceptors due to altered position of the mandible during rest. The muscle fibers make an effort towards reducing this tension and thus decrease their activity by locating the true rest position of the mandible. At no time did this residual activity cease completely, except in one subject, in the anterior fibers of the left temporal muscle, it ceased towards the end of a one minute period after the exercise of swallowing. In another subject this activity, in the posterior fibers of both sides, quieted down in thirty seconds after the exercise of swallowing. The residual activity was demonstrated immediately after the cessation of the exercise without any period of intervening relaxation.

Considerable variation was shown between subjects as illustrated in Figure 15. An analysis of variance table (Table II) also indicates highly significant difference between the subjects. Many factors could contribute to this variation. The personal subjectivity contributed greatly to the variability, since no two individuals were the same in personality or behavior. The posture of the head also had an influence on the activity of the temporal muscle. Pruzansky (1955) and Carter (1959) recorded low amplitude activity from the temporal muscles when the head was rotated to the right or left, while maintaining it in the same horizontal plane. Jarabak (1957) noticed that a slight change in the position of the head would change the activity of the temporal muscles. Vanoucek (1957) also has shown that the minimum muscular activity, associated with the postural position of the

mandible, was sometimes affected by head inclinations. Despite the fact that the head position was controlled by the use of a mirror (Fig. 5), variation may have resulted from faulty head orientation because of previous posture habits. Although the physical conditions of the subjects varied during the different hours of the day, variation due to time was minimized as much as possible by collecting records during the afternoon hours.

This experiment was designed to reveal the presence of interactions between the main sources of variations. Three interactions were highly significant as shown in Table II. The activity of the different muscle fibers varied in all individuals, since it depended on the subjects' physical and physiological conditions at the time when the records were taken. Similarly the activity of the temporal muscle of both sides was asymmetrical. This asymmetry of the activity could be due to many factors mentioned previously in this study. The patterns of speaking, swallowing, and opening the mouth maximally varied in an individual and between the individuals. The remaining interactions were not significant, and so were grouped as "residue".

It was necessary to record the duplicate readings so as to measure the reproductibility of the activity of the individual. In this experiment two readings were selected at random from four or five consecutive recordings of the activity of the temporal muscles at mandibular rest. The estimate of error due to duplicate readings was identical with the estimate of error due

to residue, and so the sum of the squares of these two errors were added together to get the estimate of the total experimental error (Table II). Thus it may be concluded that no findings could attribute purely or even remotely to the change in the muscular activity in spite of the constantly low values in amplitude.

CHAPTER V

SUMMARY AND CONCLUSION

A crystograph was used in conjunction with the electromyographic equipment to study the residual activity in the temporal muscles during mandibular rest in edentulous subjects. This study included ten edentulous subjects between the ages of forty and seventy years, who had all their teeth extracted two months to one year prior to the testing. The right and left temporal muscles were studied in three parts; the anterior, middle and posterior fibers. One minute rest activity was recorded after the cessation of three selected exercises, i.e., saying "Mississippi", swallowing, and maximal opening. Each exercise was repeated ten times before bringing the mandible to rest.

The following conclusions were based on the qualitative and quantitative analysis of the data collected:

1. The residual activity was recorded from the temporal muscles during the mandibular rest in all subjects. One subject, however, showed this activity only after the exercise of maximal opening.
2. The onset of the residual activity was recorded immediately after the cessation of exercises, without any period of complete intervening relaxation, and it was continued for the entire one minute period in most subjects. This residual activity decreased in amplitude and frequency for about forty-five seconds after its onset.

3. The anterior fibers of the temporal muscle were least active while maintaining mandibular posture; the middle fibers were more active than the anterior fibers; the posterior fibers were the most active.
4. The residual activity obtained after the exercise of saying "Mississippi" was least in amplitude and frequency; that after the exercise of swallowing was greater; and that after the exercise of maximal opening was greatest.
5. The left temporal muscle showed more activity than the right temporal muscle in all subjects except one, who showed more activity in the right temporal muscle.
6. The analysis of variance showed significant difference between the subjects. There was no relationship between the age of the subjects and the residual activity recorded from their temporal muscles.
7. There was also no relationship between the length of time these subjects were edentulous prior to their testing and their recorded residual activity.

CHAPTER VI
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TABLE I

Number	Name of Subjects	Age in Years	Edentulous* in months	Average Microvolt-second**
1.	Lewandowski, Joseph	44	2	138.7684
2.	Fletcher, James	42	2	71.4025
3.	Pippenger, Guy	68	5	397.2049
4.	Walter, Juris	52	3	66.9124
5.	Crump, Jim	65	9	87.4225
6.	Kluk, Stanley	47	2	46.2400
7.	Magiera, Thomas	70	12	59.5984
8.	Martie, Joe	49	12	123.8769
9.	Mitchell, Joseph	55	11	7.4529
10.	Phillips, Jack	69	8	37.3321

* Approximate time in months during which the patient was edentulous,
i.e., from the day last tooth was extracted to the recording was made.

** Average energy output per second by all muscle groups.

TABLE II

Sources of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Variance Ratio
Subjects	9	26,865.4606	2,985.0511	391.3897***
Muscle Groups	2	22,332.6260	11,166.3130	29.9887***
Sides	1	2,989.7868	2,989.7868	7.1221*
Activity	2	351.1444	175.5722	1
Periods	3	90.3898	30.1299	3.95**
Su. x Gr. Inter.	18	6,702.3141	372.3507	48.8213***
Su. x Sides Inter.	9	3,702.3141	419.7866	55.0409***
Su. x Act. Inter.	18	4,350.6447	241.7024	31.6911***
Error	1,377	10,502.1505	7.6268	
Total	1,439	78,535.1616		

APPROVAL SHEET

The thesis submitted by Dr. Naishadh Parikh has been read and approved by four members of the Departments of Anatomy and Oral Anatomy.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

8-17-66
Date

Joseph R. Susantika
Signature of Adviser